

Summary of WG IV: Spin structure

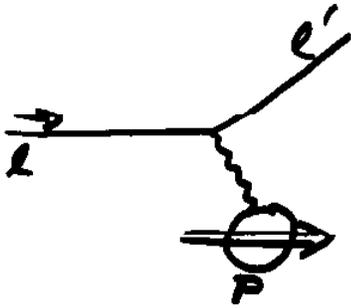
1. Introduction
2. New experimental results on the Spin Structure of the Nucleon (inclusive)
3. QCD interpretation
4. Theoretical developments
5. New experimental results (semi-inclusive)
6. Future Spin - experiments
7. Summary and Conclusions

Convenors:

E.W. Hughes, K.Rith, T. Gehrmann

22 talks

Polarized Deep Inelastic Scattering



$$\frac{d^2\sigma}{dx dQ^2} = \frac{4\pi\alpha^2}{xQ^4} [xy^2 F_1 + (1-y - \frac{\gamma^2}{4}) F_2]$$

$$\frac{d^2\sigma_{\parallel}}{dx dQ^2} = \frac{16\pi\alpha^2 y}{Q^4} [(1-\frac{y}{2} - \frac{\gamma^2}{4}) g_1 - \frac{\gamma^2}{2} g_2]$$

$$\frac{d^2\sigma_{\perp}}{dx dQ^2} = -\cos\phi \frac{8\pi\alpha^2 y}{Q^4} \gamma \sqrt{1-y-\frac{\gamma^2}{4}} [\frac{y}{2} g_1 + g_2]$$

$$A_{\parallel} = \frac{\Delta\sigma_{\parallel}}{2\sigma}$$

$$= D(A_1 + \eta A_2)$$

$$A_{\perp} = \frac{\Delta\sigma_{\perp}}{2\sigma}$$

$$= d(A_2 + \xi A_1)$$

recent experimental results:

HERMES, E154, SMC

HERMES (U. Stöblein)

→ fig.

- new experiment operating a polarized internal gas target in the polarized HERA e^+ beam.
- unique reconstruction of hadronic final state

1995 run: unpolarized test runs and polarized ^3He -target

results: • $g_1^n(x, Q^2)$ → fig.
- $\Gamma_1^n(Q^2=2.5 \text{ GeV}^2) = -0.037 \pm 0.013 \pm 0.003$

1996 run: polarized H-target
⊕ no dilution factor

results: • error bars smaller by a factor 5 with respect to ^3He measurement
• $g_1^p(x, Q^2)$ will soon be released

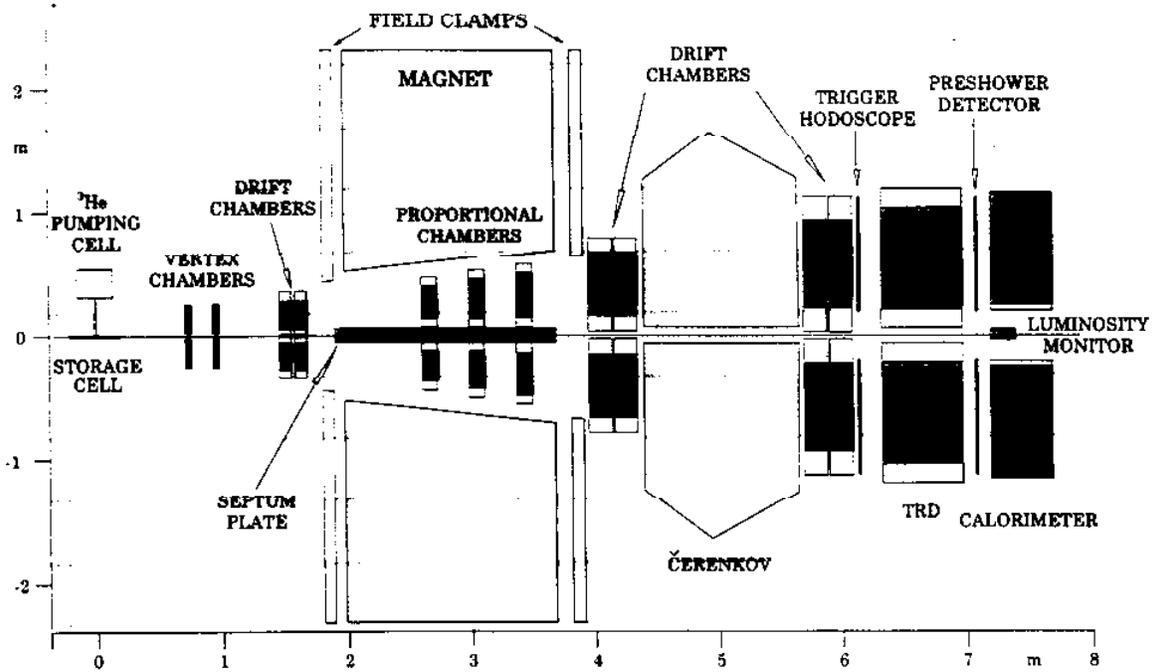
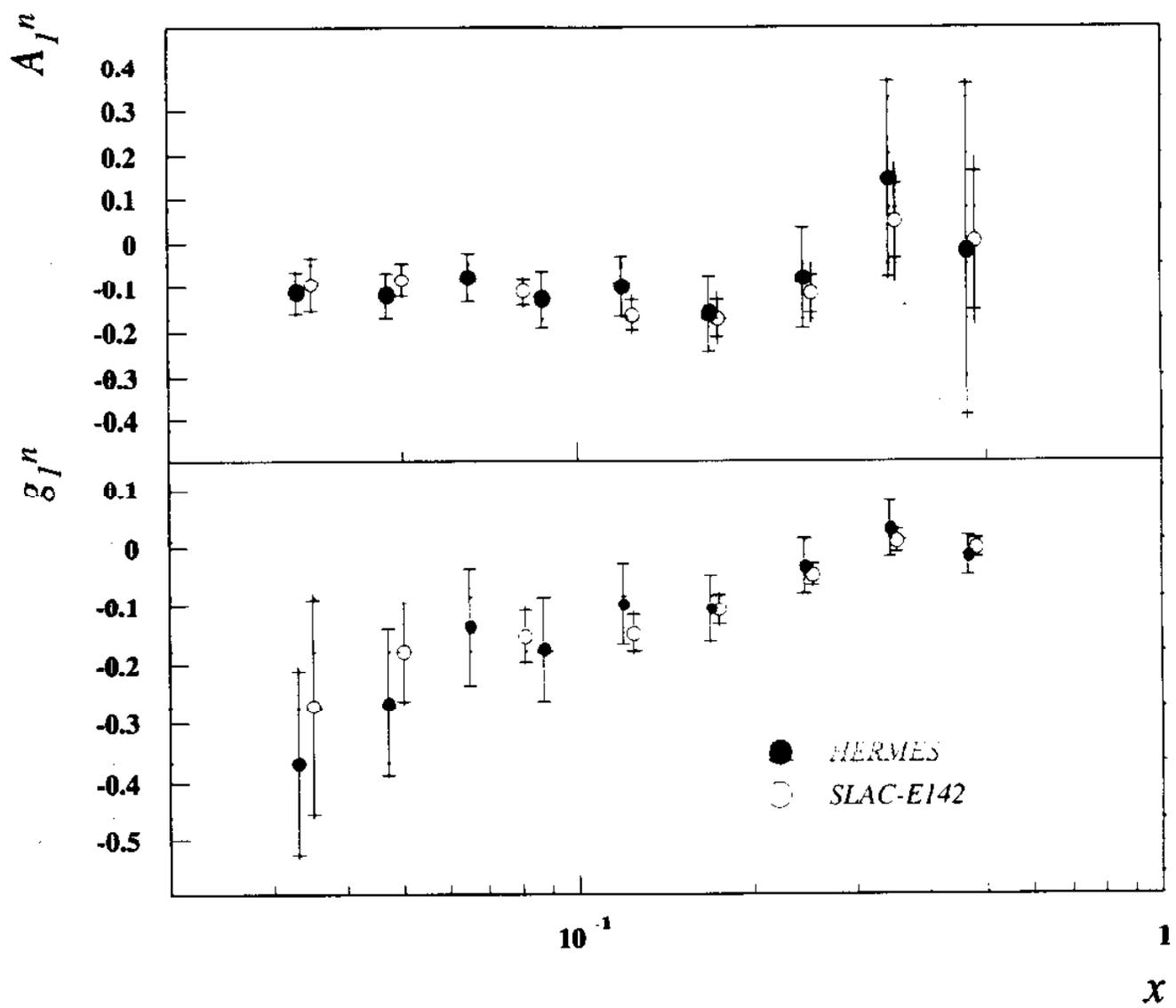


FIG. 1. Schematic diagram of the experimental apparatus (side view).



E154/E155 (Z. Meiziani)

→ fig.

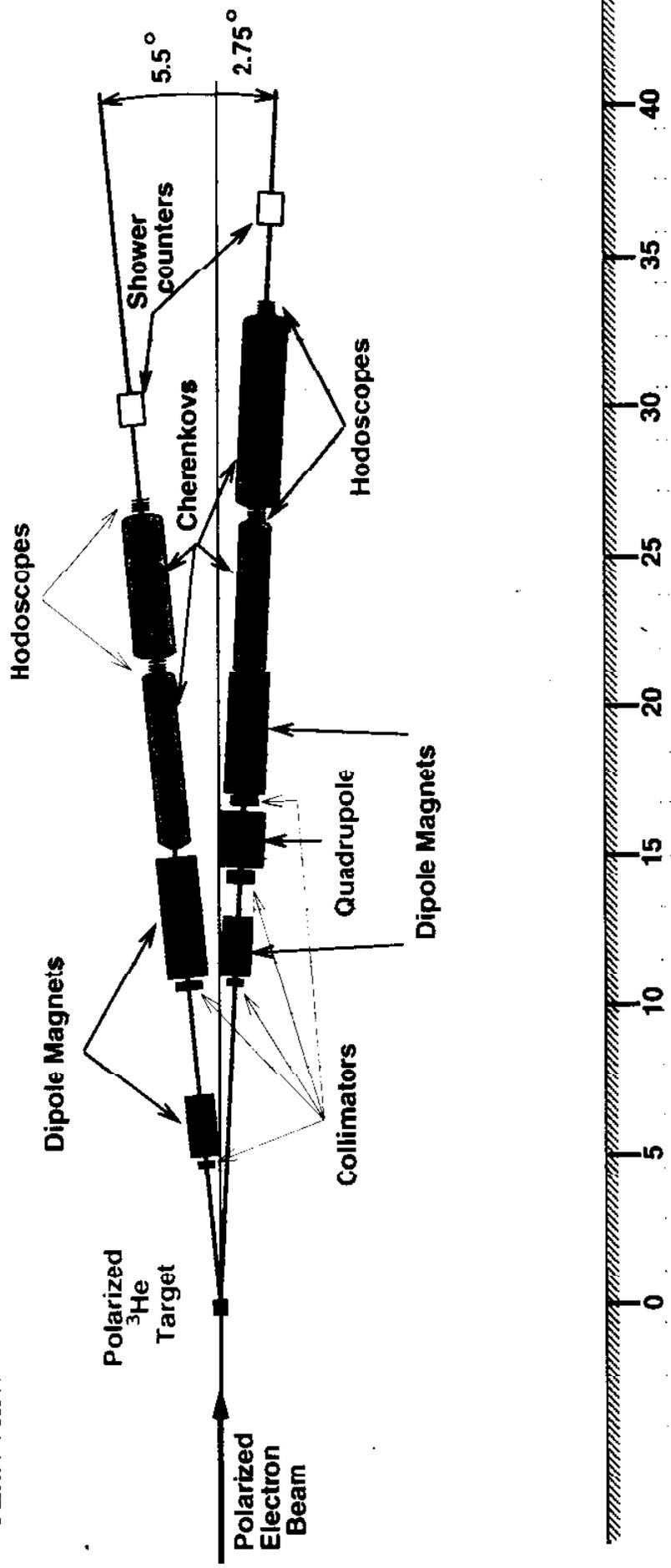
- higher beam energy (50 GeV) and beam polarization (82%) than earlier SLAC measurement

E154: polarized ^3He -target

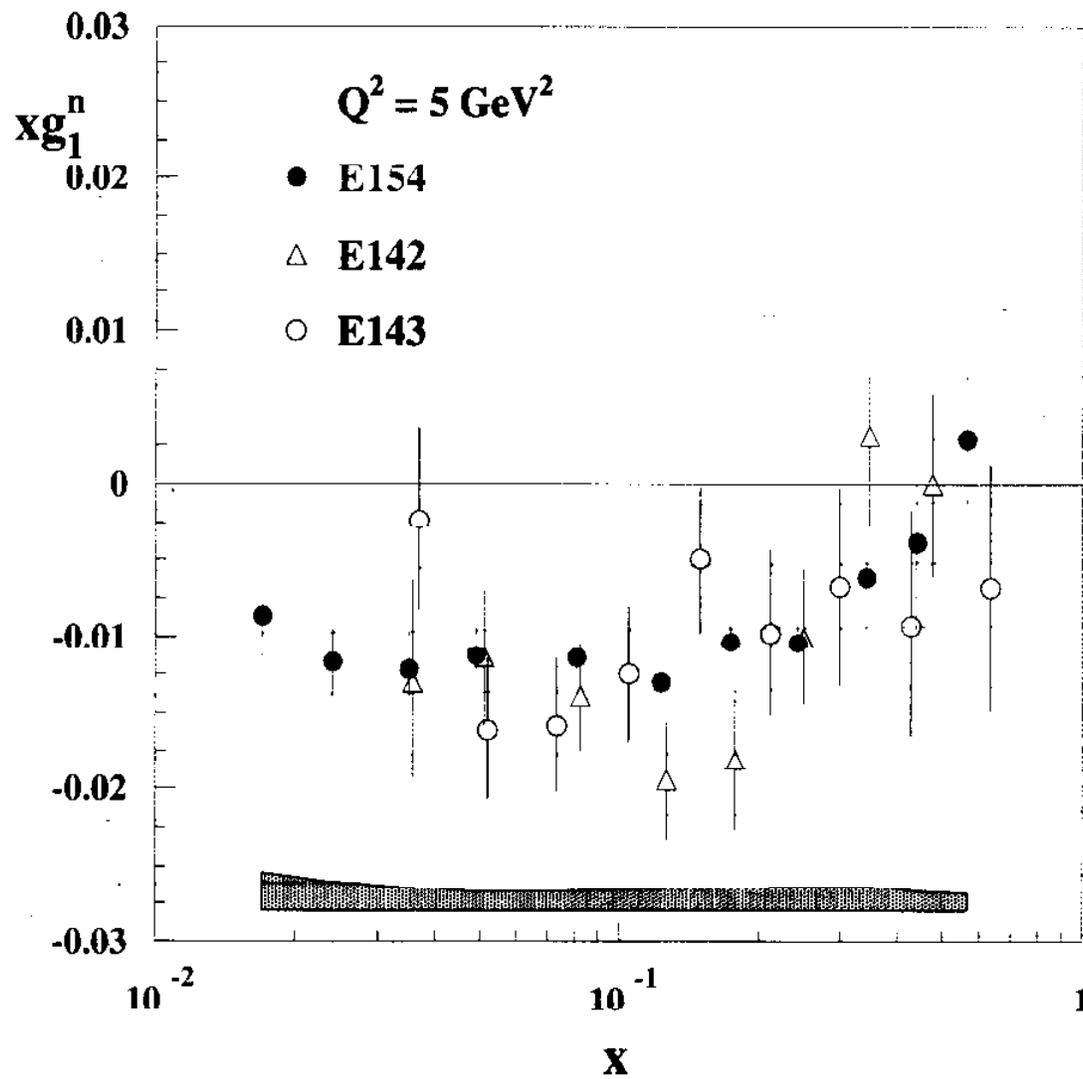
- results:
- $g_1^n(x, Q^2)$ → fig.
 - $\Gamma_1^n(Q^2 = 5 \text{ GeV}^2) = -0.041 \pm 0.004 \pm 0.006$
(value relies heavily on extrapolation towards $x \rightarrow 0$) → fig.
 - $g_2^n(x, Q^2)$ → fig.
 - d_2^n as probe of higher twist → tab.

E154 Setup

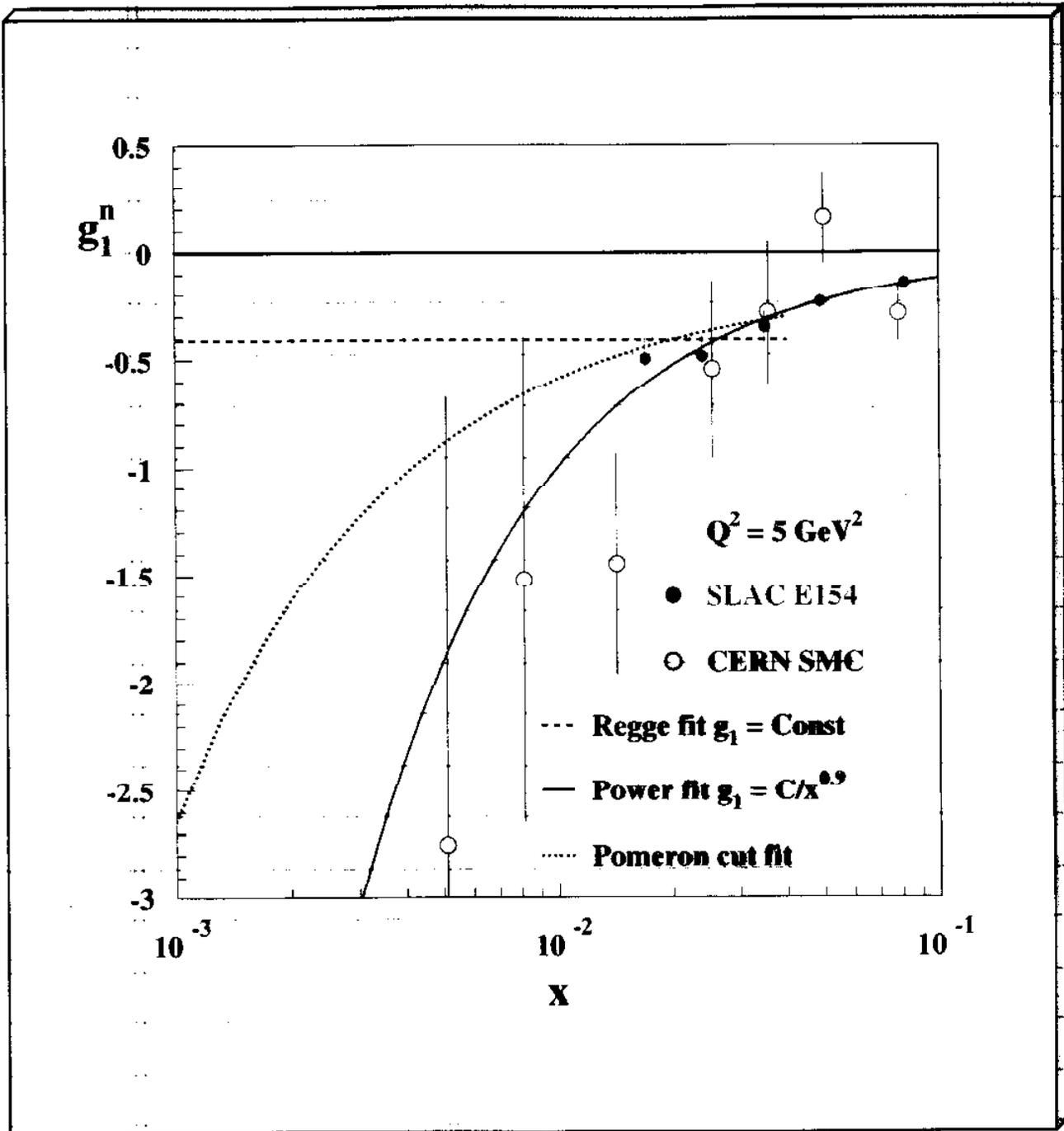
PLAN VIEW



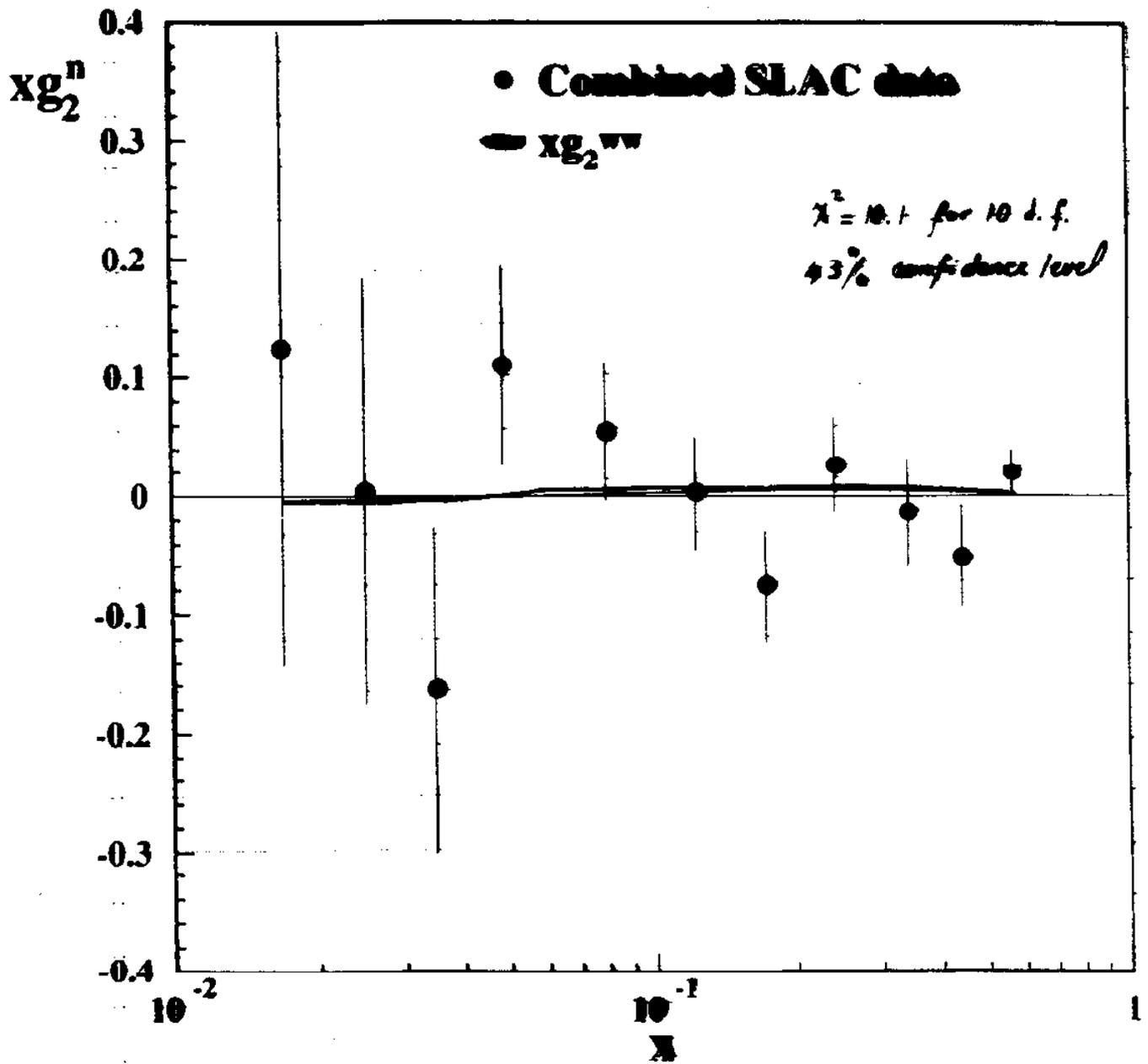
SLAC Experiments



Low x fits



Neutron xg_2



Comparison of Experimental and Theoretical Results for the Reduced Twist-3 Matrix Element

	$\bar{d}_2^n \times 10^2$	$Q^2(\text{GeV}/c)^2$
EL54 result	-0.3±3.8	5.0
SLAC Average	-1.0±1.6	5.0
QCD sum rule [1]	-3±1	1.0
QCD sum rule [2]	-2.7±1.2	1.0
Bag Model [3]	0	5.0
Bag Model [4]	-0.253	5.0
Bag Model [5]	0.03	5.0
Lattice QCD [6]	-0.39±0.27	4.0

- [1] E. Stein *et al.*, Phys. Lett. B 343 (1995) 369.
- [2] I. Balitsky *et al.*, Phys. Lett. B 242 (1990) 245.
- [3] X. Ji and P. Unrau, Phys. Lett B 333 (1994) 228.
- [4] X. Song, Phys. Rev. D 54 (1996) 1955.
- [5] M. Stratmann, Z. Phys. C 60 (1993) 763.
- [6] M. Gökeler *et al.*, Phys. Rev. D 53 (1996) 2317.

SMC (A. Magnon)

→ fig.

1996 run: polarized proton structure
from NH_3 -target

⊕ Better dilution factor than
Buthanol target used before

preliminary results:

• $\underline{g_1^p(x, Q^2)}$

→ fig.

- $g_1^p(x, Q^2)$ does not rise at small x

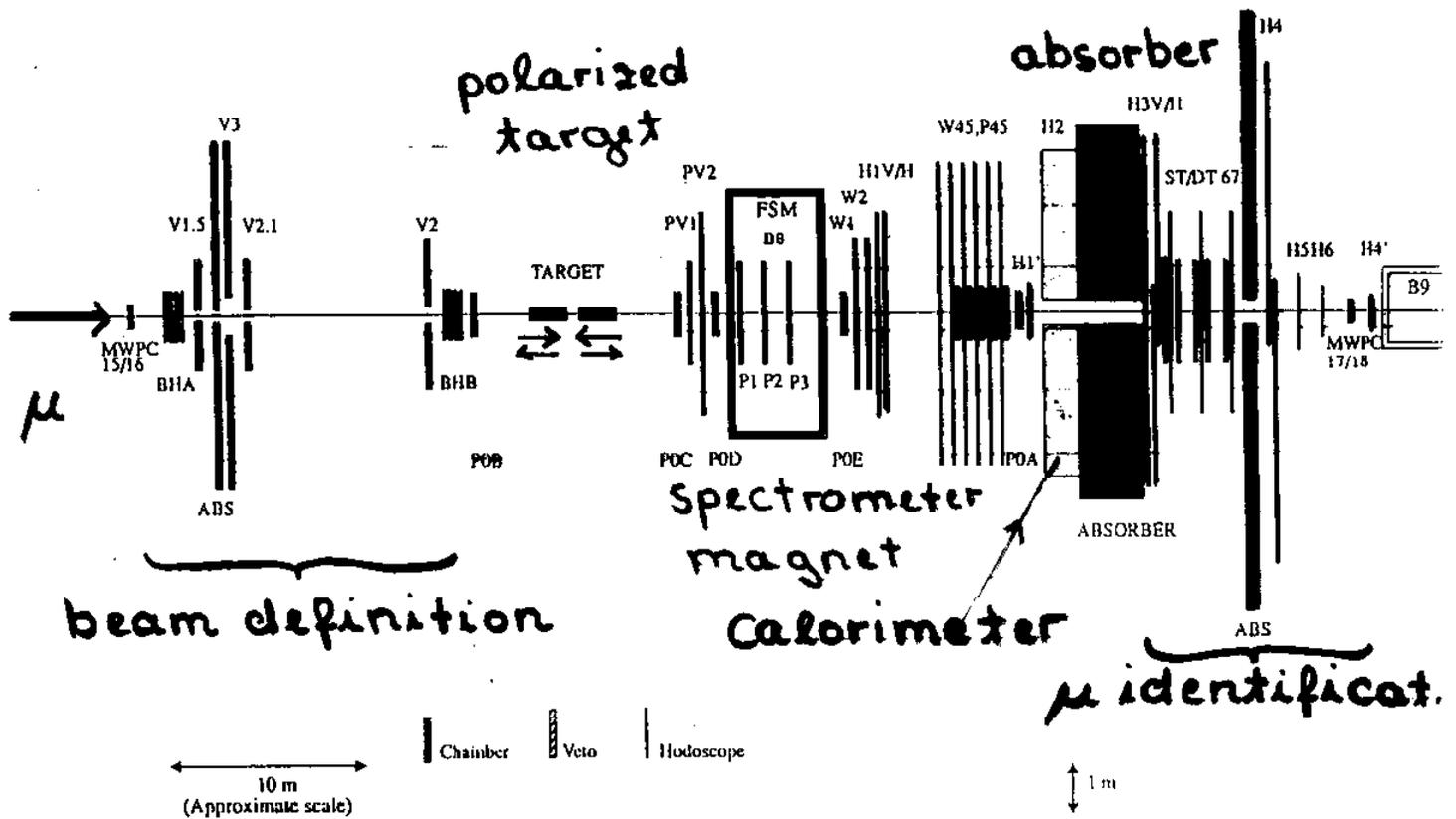
- $\Gamma_1^p(Q^2 = 10 \text{ GeV}^2) = 0.149 \pm 0.012$ ('93+'96)

• $\underline{A_2^p(x, Q^2)}$

→ fig.

- consistent with 0

SMC experiment



Measurement of

incoming + scattered μ

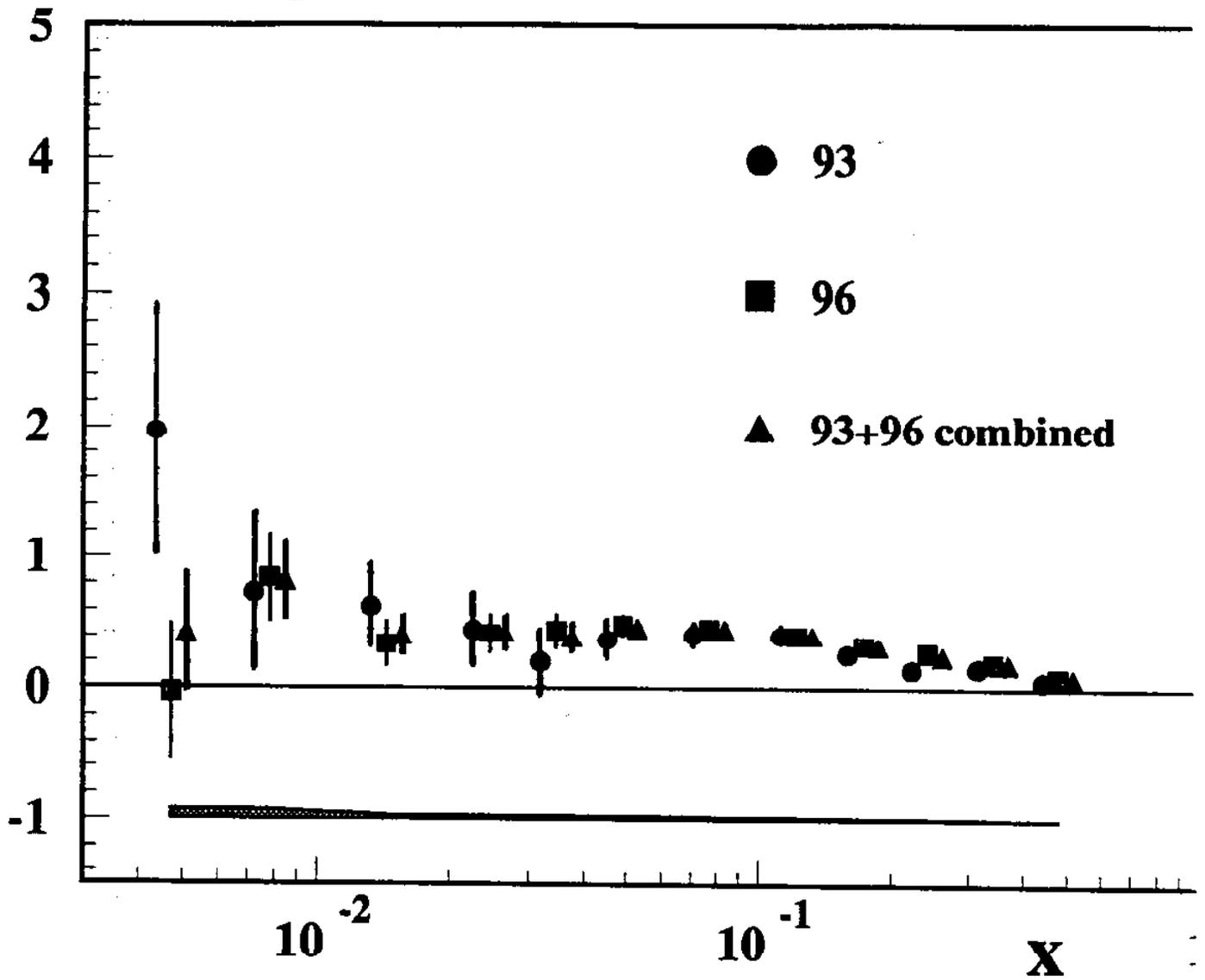
charged hadrons $p_h > 5 \text{ GeV}$

neutral hadrons via decay
vertex or γ conversion

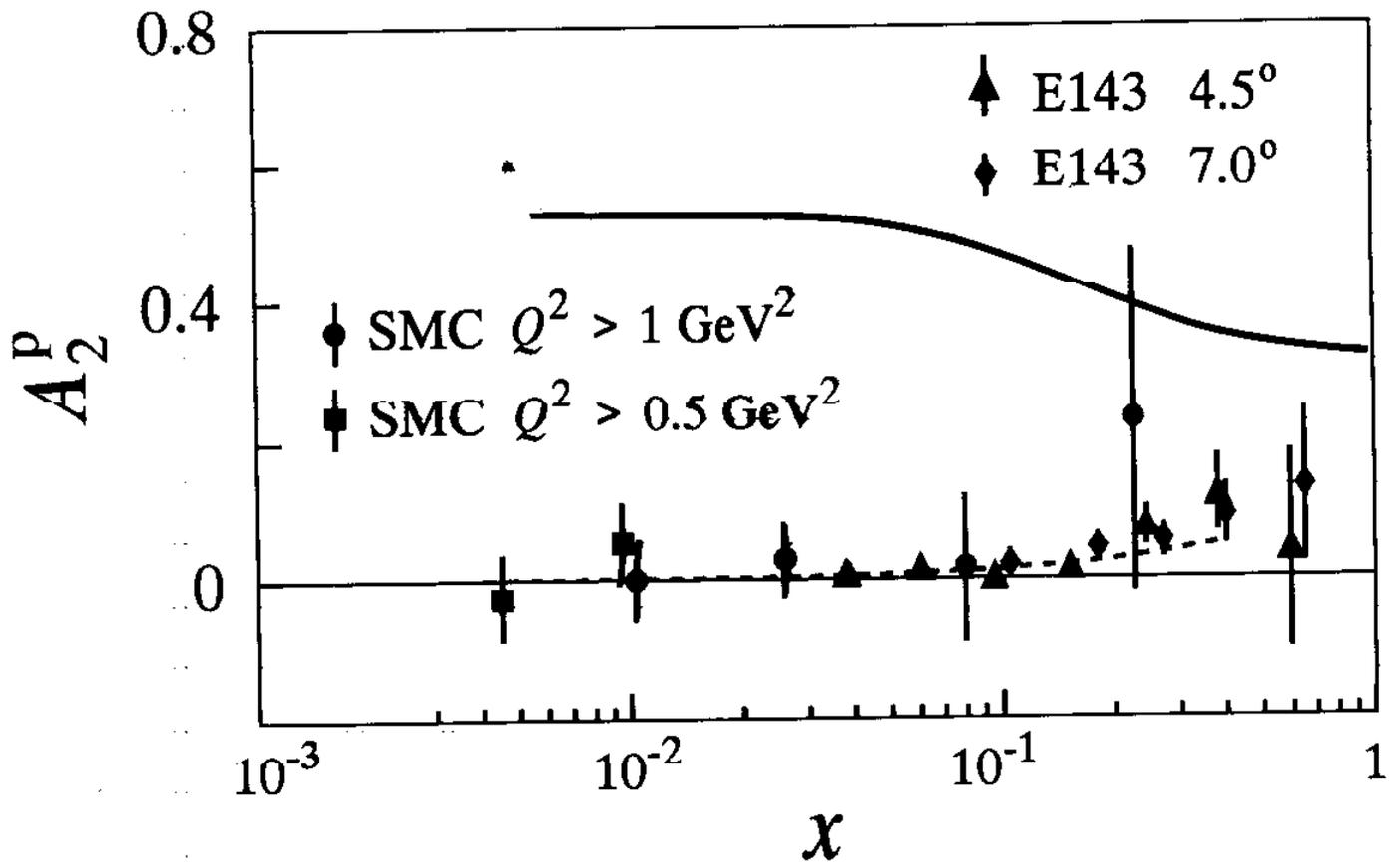
SMC 93 & 96

g_1^p at measured Q^2

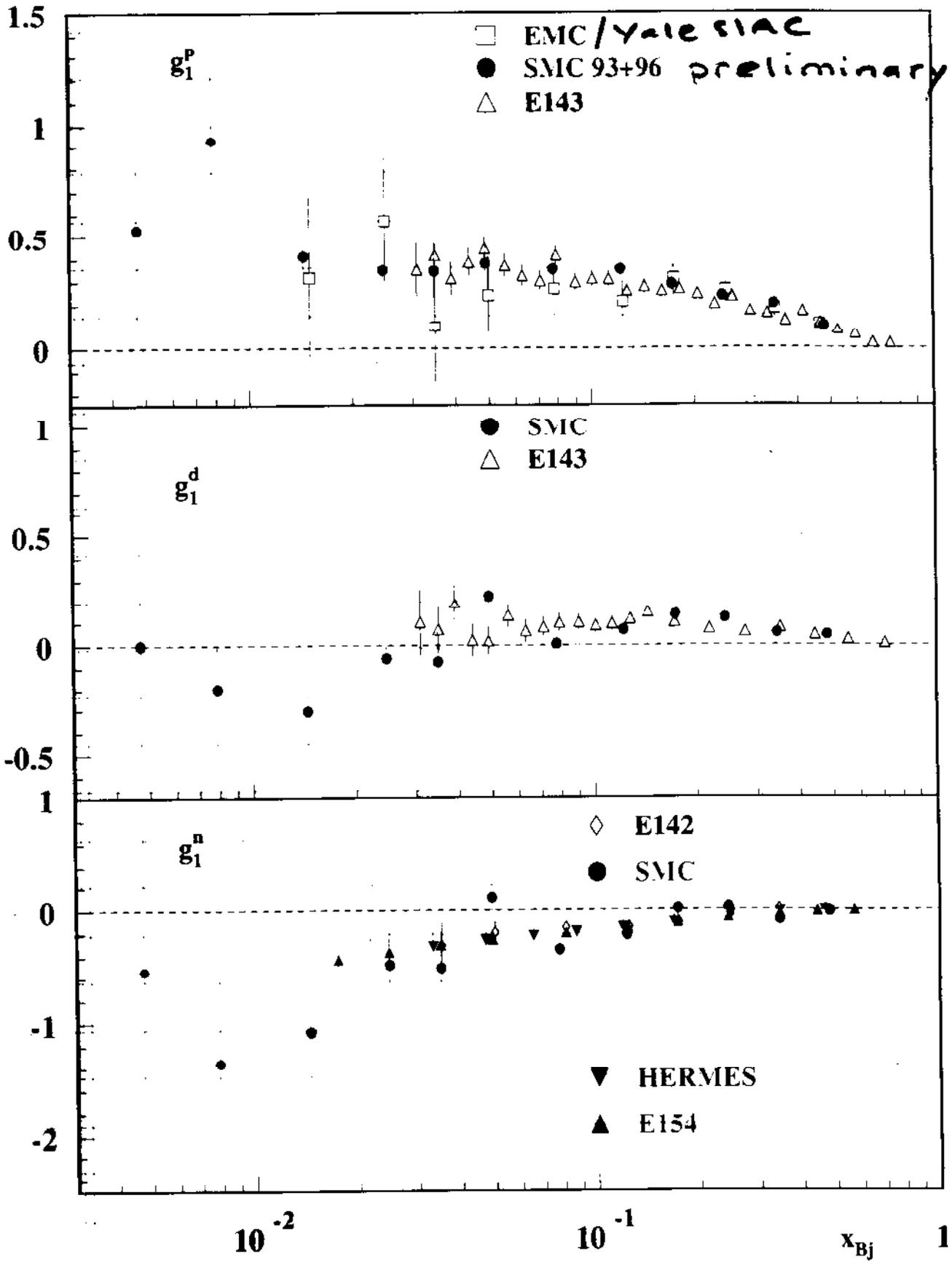
preliminary



A_2^P SMC E143



World Data at $Q^2 = 5 \text{ GeV}^2$



recall: $g_1(x, Q^2) = \frac{1}{2} \int_x^1 \frac{dy}{y} \sum_q e_q^2 [\Delta C_q(y) \Delta q(\frac{x}{y}, Q^2) + \Delta C_g(y) \Delta G(\frac{x}{y}, Q^2)]$

for polarized parton distributions

$$\Delta \Sigma(x, Q^2) = \sum_q \Delta q(x, Q^2) + \Delta \bar{q}(x, Q^2)$$

$$\Delta q_{NS,i}^-(x, Q^2) = \Delta q_i(x, Q^2) - \Delta \bar{q}_i(x, Q^2)$$

$$\Delta q_{NS,i}^+(x, Q^2) = \sum_{n=1}^{i-1} (\Delta q_n(x, Q^2) + \Delta \bar{q}_n(x, Q^2)) - (i-1) (\Delta q_i(x, Q^2) + \Delta \bar{q}_i(x, Q^2))$$

olve according to the DGLAP equations:

$$\frac{\Delta \Sigma(x, Q^2)}{d \ln Q^2} = \int_x^1 \frac{dy}{y} [\Delta P_{qq}(y) \Delta \Sigma(\frac{x}{y}, Q^2) + 2\alpha_s \Delta P_{qg}(y) \Delta G(\frac{x}{y}, Q^2)]$$

$$\frac{\Delta G(x, Q^2)}{d \ln Q^2} = \int_x^1 \frac{dy}{y} [\Delta P_{gq}(y) \Delta \Sigma(\frac{x}{y}, Q^2) + \Delta P_{gg}(y) \Delta G(\frac{x}{y}, Q^2)]$$

$$\frac{d \Delta q_{NS,i}^\pm(x, Q^2)}{d \ln Q^2} = \int_x^1 \frac{dy}{y} \Delta P_{qq,NS}^\pm(y) \Delta q_{NS,i}^\pm(\frac{x}{y}, Q^2)$$

use data on $y_1(x, Q^2)$ to fit the polarized parton distributions

- SMC
- Ezya (1)
- Altarelli, Forte, Pi

motivation:

) polarized parton distributions are universal features of the nucleon

- enable calculation of other spin observables
- can be compared to lattice calculations or non-perturbative models

) data on $A_1(x, Q^2)$ are not taken at common

so far: assumed $A_1(x, Q^2)$ (contradicts D1)

now: use results of QCD analysis to "evolve" $A_1(x, Q^2)$ -data to common

resulting distributions can estimate the behaviour of $y_1(x, Q^2)$ at small x .

work in \overline{MS} scheme

(alternatively used: Adler-Bardeen scheme w
non-zero gluonic contribution to $\Gamma_1(Q^2)$)

fit only total sea quark polarization

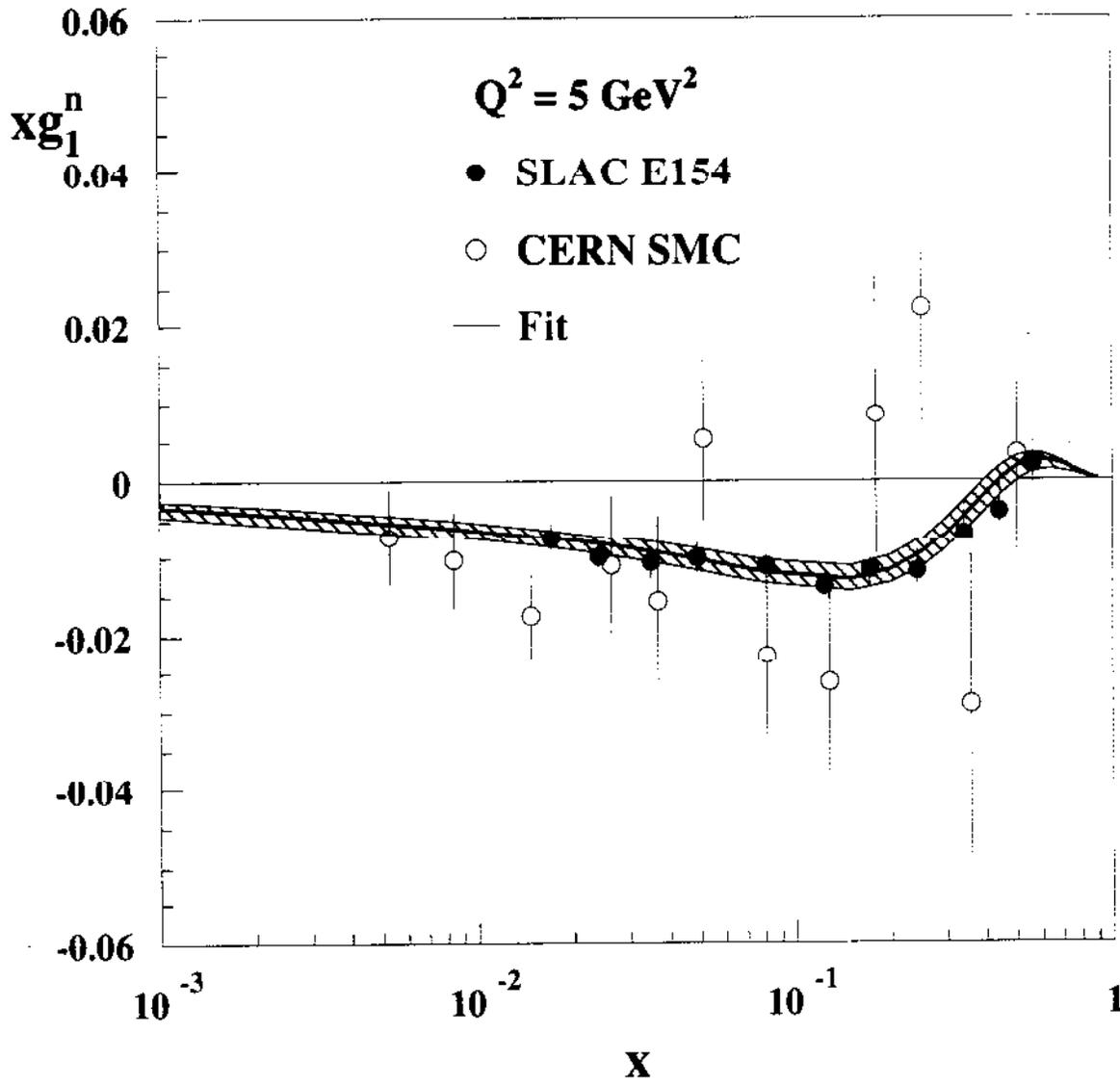
results of the fit for $Q^2 = 5 \text{ GeV}^2$ $\rightarrow f_1$
 $\rightarrow t$

evolution of $xg_1^n(x, Q^2)$ to common Q^2 $\rightarrow f$

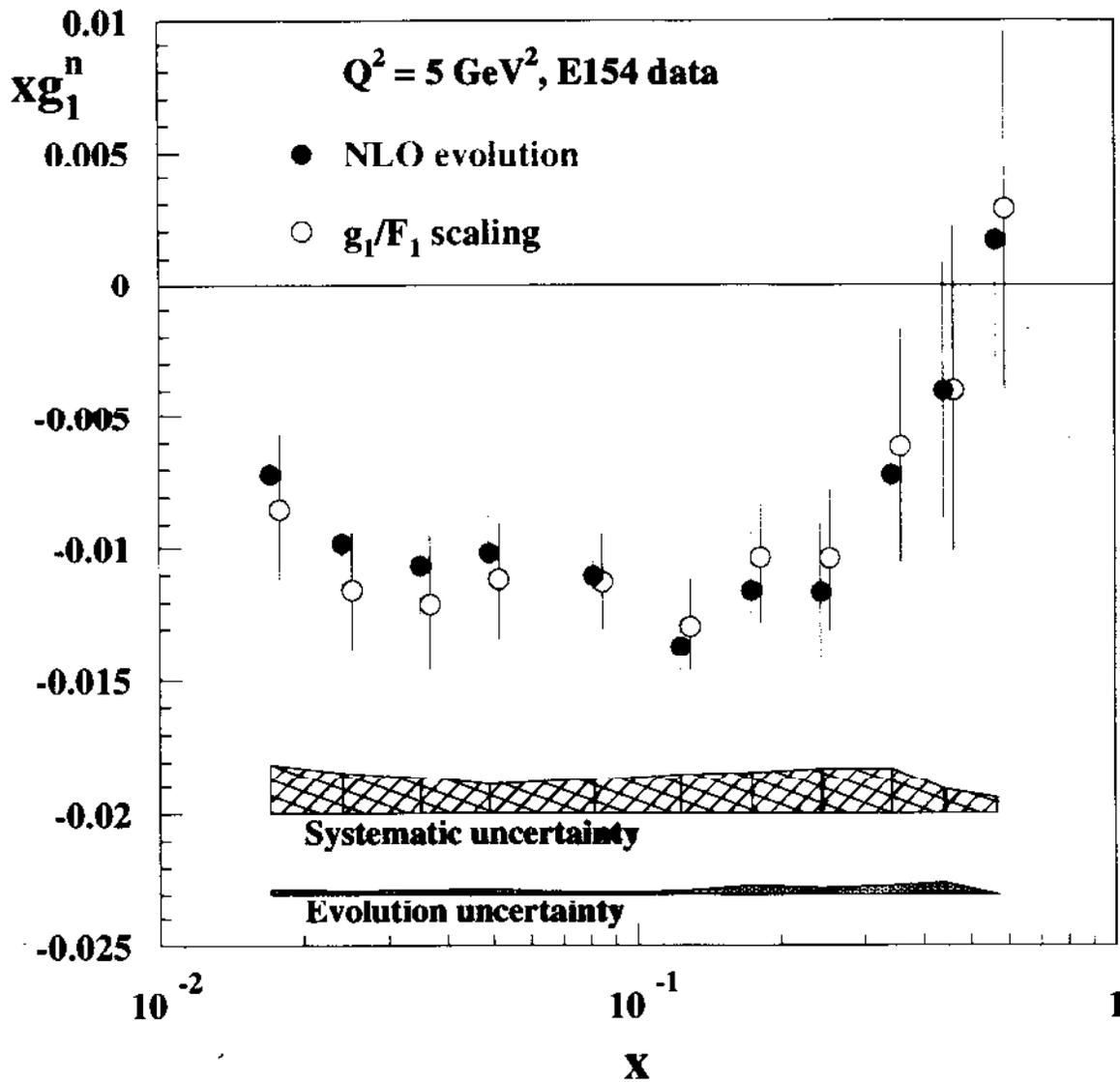
large negative contribution to neutron sp
sum from $x < x_{\text{min}}$ suggested

	Value	Stat.	Syst.	Theory
Δuv	0.69	+0.03 -0.02	+0.05 -0.04	+0.14 -0.01
Δdv	-0.40	+0.03 -0.04	+0.03 -0.03	+0.07 -0.00
$\Delta \bar{Q}$	-0.02	+0.01 -0.02	+0.01 -0.01	+0.00 -0.03
ΔG	1.8	+0.6 -0.7	+0.4 -0.5	+0.1 -0.6
Δq_3	1.09	+0.03 -0.02	+0.05 -0.05	+0.06 -0.01
Δq_8	0.30	+0.06 -0.05	+0.05 -0.05	+0.23 -0.01
$\Delta \Sigma$	0.20	+0.05 -0.06	+0.04 -0.05	+0.01 -0.01
Γ_1^p	0.112	+0.006 -0.006	+0.008 -0.008	+0.009 -0.001
Γ_1^n	-0.056	+0.006 -0.007	+0.005 -0.006	+0.002 -0.001
Γ_1^d	0.026	+0.005 -0.006	+0.005 -0.006	+0.005 -0.001
Γ_1^{p-n}	0.168	+0.005 -0.004	+0.008 -0.007	+0.007 -0.001

Neutron



Q^2 evolution



RESULTS COMMON TO ALL QCD FITS

- ⊕ $\Delta u_v(x, Q^2)$ and $\Delta d_v(x, Q^2)$ can be determined from structure function data reasonably
- ⊕ overall magnitude of sea quark polarization constrained by data
- ⊖ flavour decomposition of polarized quark sea completely undetermined
- ⊖ gluon polarization $\Delta G(x, Q^2)$ only loosely constrained $\rightarrow f$

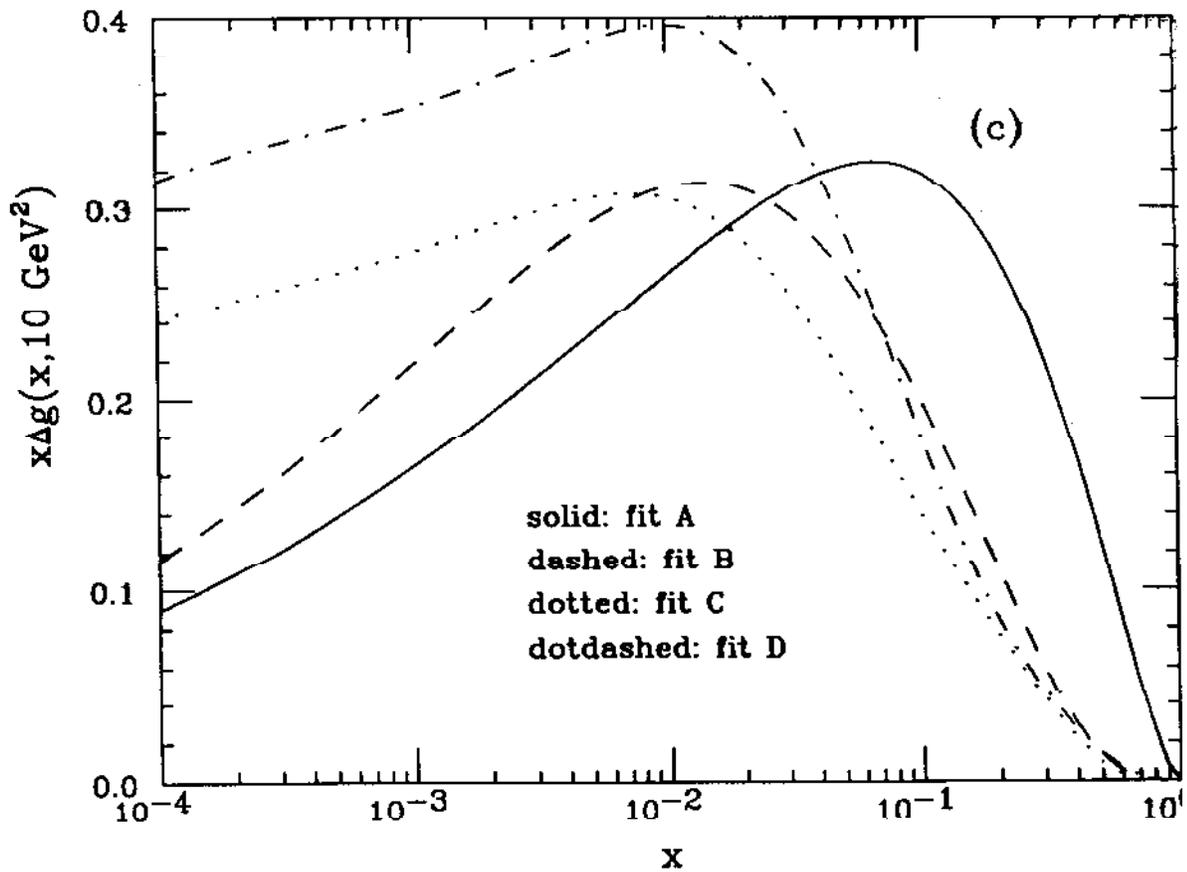
Particular in the analysis of ABFR

$$\alpha_s = 0.120^{+0.010}_{-0.008} \quad \text{fitted}$$

(essentially from scaling violations)

GLUON

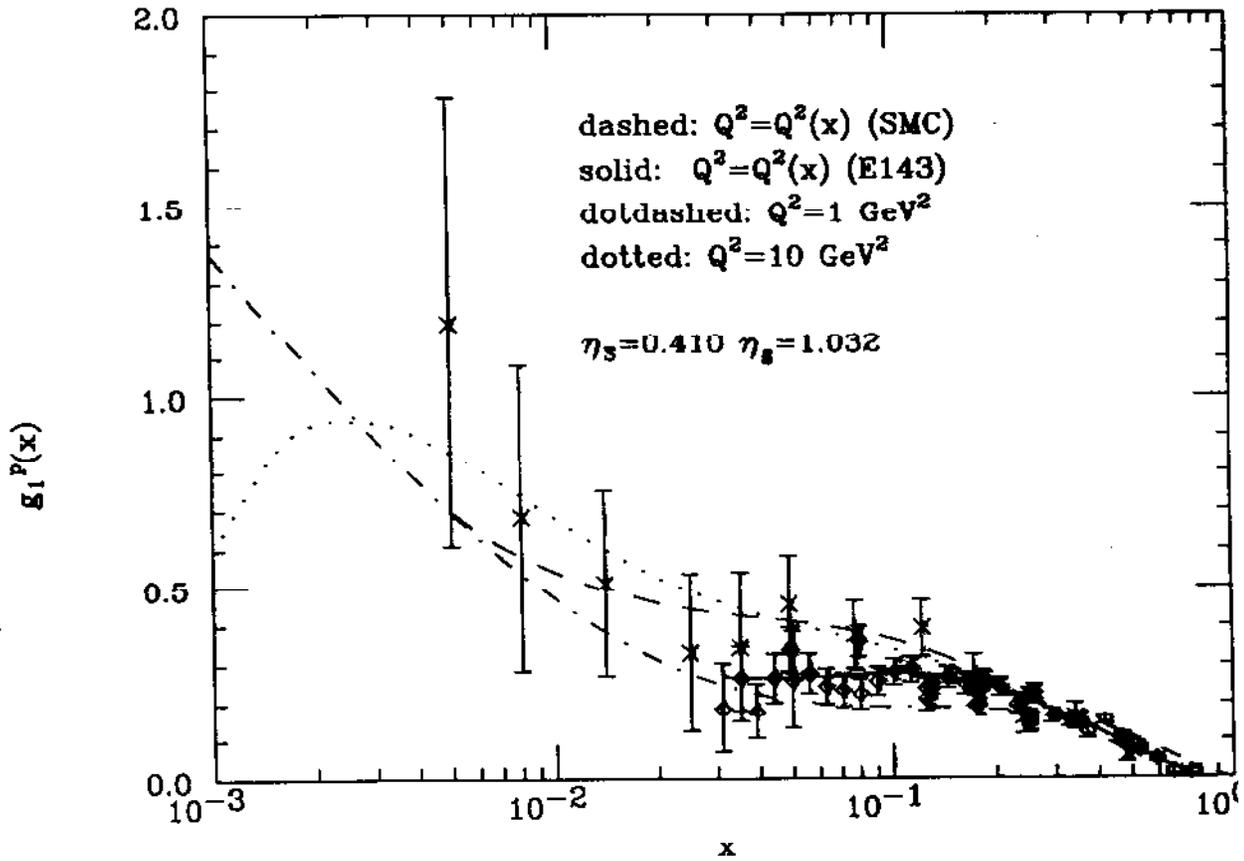
$$Q^2 = 10 \text{ GeV}^2$$



ABFR

FIT "B"

g_1 (PROTON)



polarized structure functions (Schierholz)

measure bare operators $\mathcal{O}(a)$ between proton states on a discrete lattice with spacing a
renormalize operators using (presently only perturbatively calculated renormalization constants)

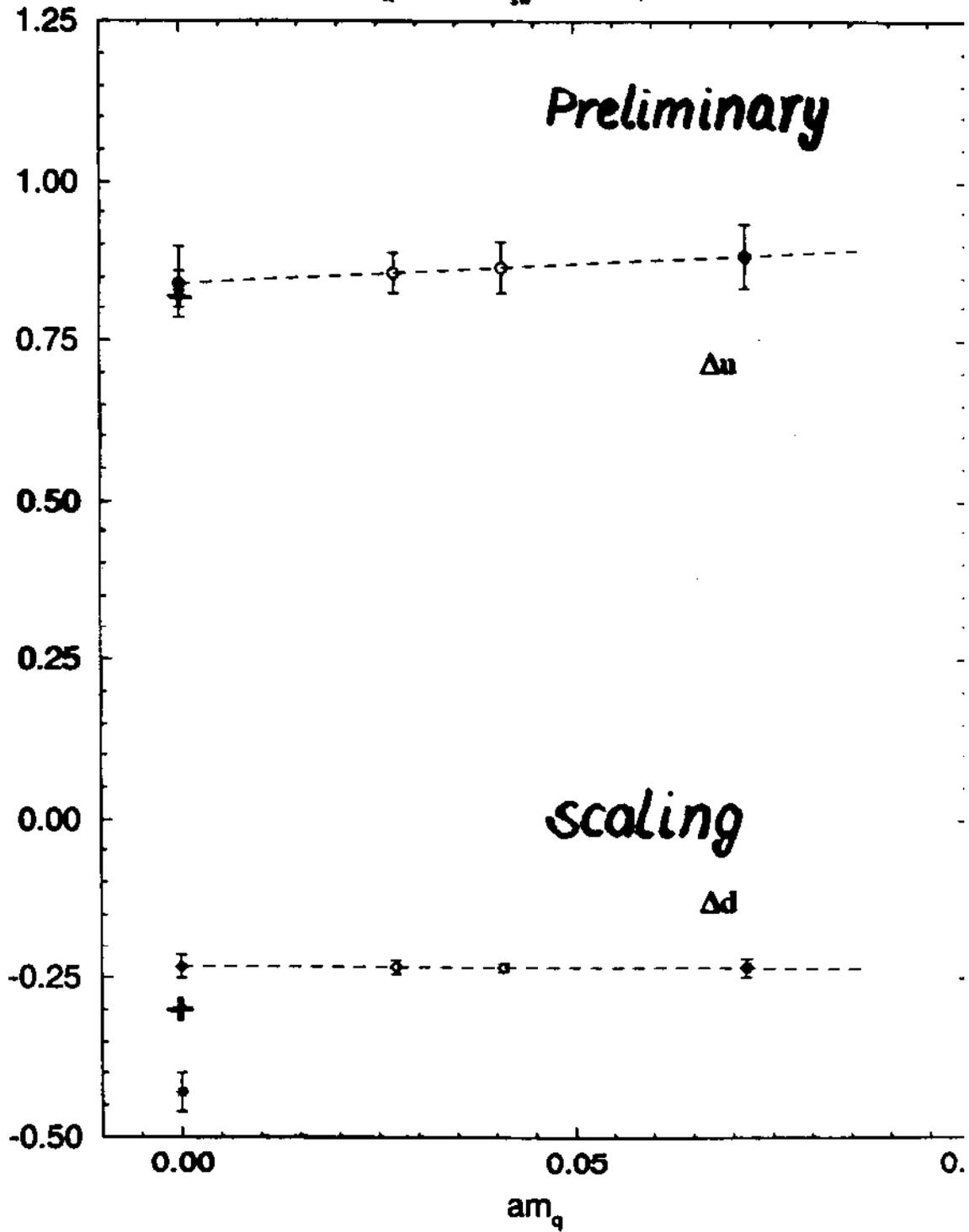
extrapolate towards continuum limit ($a=0$)
still limited by computer performance:
no dynamical fermions

present results:

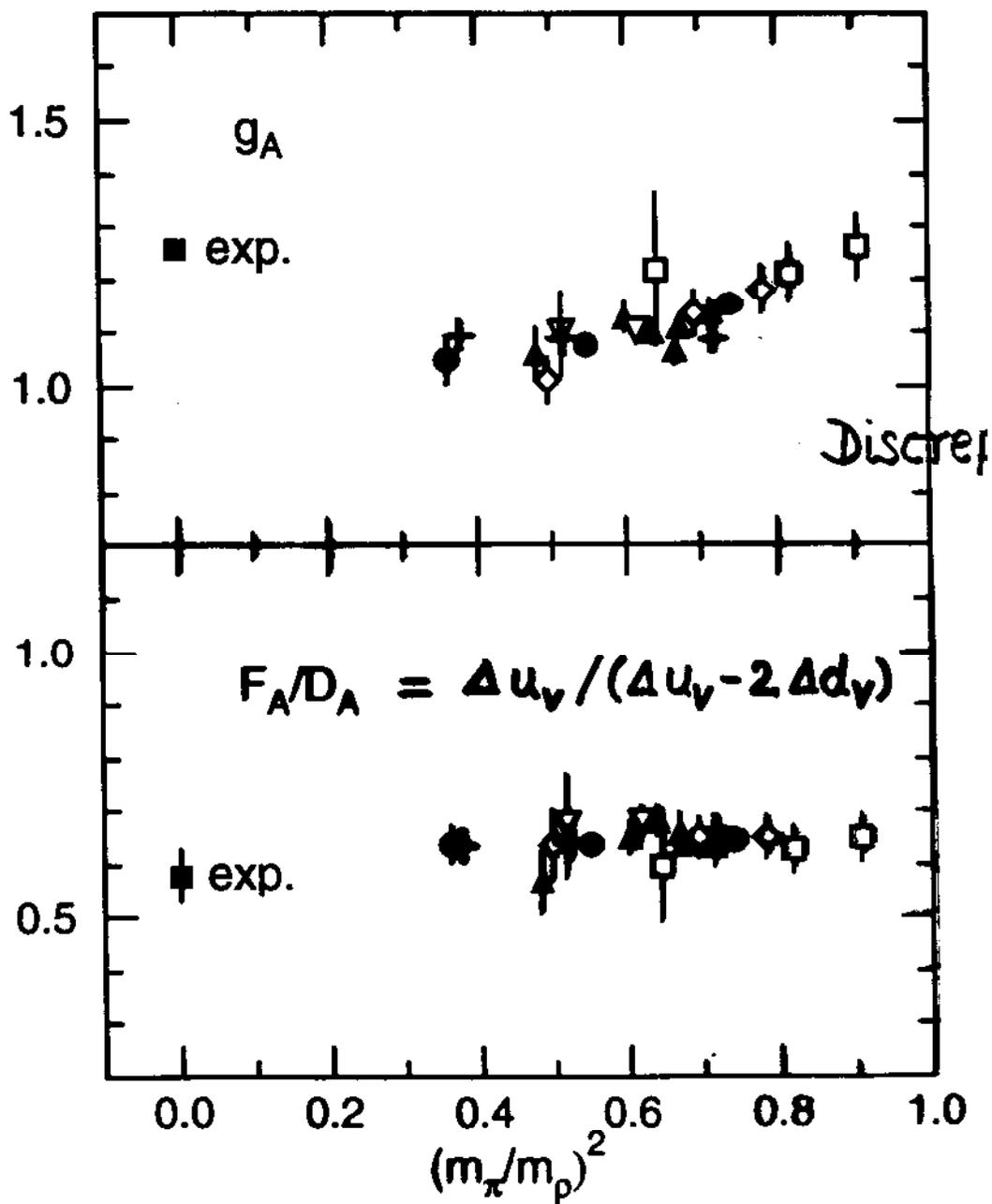
- improved measurement of first moments of $\Delta u_v, \Delta d_v$
- measurement of $SU(3)_f$ octet matrix elements: $g_A, \frac{F}{D}$

$\Delta q (p=(0,0,0), q=(0,0,0))$

$(\beta = 6.2, c_{sw} = 1.614)$



$$g_A = \Delta u - \Delta d \quad NS$$



Rests (parton)

experiment: data cover only $x > 0.005$
(small x ?)

theory: different predictions

- Regge theory: $g_1(x) \sim x^\alpha$, $\alpha \in [0; 0]$
- DGLAP: $g_{1(S, NS)} \sim \exp(\text{const} \cdot \ln \frac{1}{x} \ln \frac{Q^2}{\mu^2})$
- small- x resummations became avail recently (B. Ermolaev et al)

used on infrared evolution equations:

resummation of terms $\sim \alpha_s^n \ln^{2n-1} \frac{1}{x}$

- $g_1^{NS} \sim x^{-\sqrt{2} \alpha_s C_F / \pi} \approx x^{-0.4}$
 - $g_1^S \sim x^{-3.45 \sqrt{\alpha_s N_c / \pi}} \approx x^{-1.01}$
- } Zarkels, E, Ryskin

- $g_2^{NS} = -\frac{\partial g_1^{NS}}{\partial \ln \alpha_s} \Big|_{\alpha_L = \alpha_R = \alpha_s} \rightarrow g_2 \sim g_1$ Ermolaev

- open questions on g_2 :

- Wandzura-Wilczek
- Twist 3

INTEGRAL RELATIONS BETWEEN STRUCTURE FUNCTIONS:

J. BLÜMLEIN, N. KO

TWIST 2:

$$W_{\mu\nu}^{\parallel} = i \epsilon_{\mu\nu\alpha\beta} \frac{q_{\alpha} p_{\beta}}{\nu} g_1 + \frac{p_{\mu} p_{\nu}}{\nu} g_4 - g_{\mu\nu}$$

$$g_2 = -g_1 + \int \frac{dy}{y} g_1$$

WANDZURA-WILCZEK

$$W_{\mu\nu}^{\perp} = i \epsilon_{\mu\nu\alpha\beta} \frac{q_{\alpha} s_{\perp\beta}}{\nu} (g_1 + g_2) + \frac{p_{\mu} s_{\nu}^{\perp} + p_{\nu} s_{\mu}^{\perp}}{2\nu} g_3$$

$$\left[\begin{array}{l} g_4 = 2x g_5 \\ \text{DICUS} \end{array} \right]$$

$$g_3 = 4x \int \frac{dy}{y} g_5$$

BLÜMLEIN-KO

$$\frac{p_{\mu} s_{\nu}^{\perp} + p_{\nu} s_{\mu}^{\perp}}{2\nu} g_3$$

OPE & KOV. PAR. MODELL.

TWIST 3:

$$g_2^{\parallel} = g_2 + g_1 - \int_x^1 \frac{dy}{y} g_1(y) \quad (\text{TWIST 2} = 0)$$

$$g_3^{\parallel} = g_3 - 4x \int_x^1 \frac{dy}{y} g_5(y) \quad (\text{TWIST 2} = 0)$$

OPE

$$12 \left[x g_2^{\parallel}(x, Q^2) - \int_x^1 dy g_2^{\parallel}(y, Q^2) \right] \stackrel{\gamma_P - \gamma_N}{=} g_3^{\parallel}(x, Q^2)$$

SINCE $a_n \neq a_n$ IN GENERAL.

• (NEW) EFREMOV-LEADER-TERAEV SR. (JUI

$$I = \int_0^1 dx \times [g_1^V(x) + 2g_2^V(x)] = 0.$$

HOW CAN THIS BE VIEWED IN OPE ?

CONSIDER g_1^-, g_2^- & $g_A \rightarrow 0$ (CC)

$$\wedge \quad I = \frac{e_q^2}{8} d_1^{Vq} \quad \leftarrow \text{TWIST 3.}$$

$$\begin{aligned} & \langle PS | \bar{q} (\gamma_\beta \gamma_5 D^\mu - \gamma_\mu \gamma_5 D^\beta) q | PS \rangle \\ & = d_1^{Vq} (S^{\beta\mu} - S^{\mu\beta}) = m_q \langle PS | \bar{q} i \gamma_5 \sigma^{\beta\mu} q | PS \rangle \\ & \quad \quad \quad \uparrow \text{finite.} \end{aligned}$$

$$\rightarrow d_1^{Vq} \equiv 0 \quad \text{IN MASSLESS QCD}$$

(*) IS CONSISTENT WITH OPE, BUT CANNOT BE DERIVED, AS E.G. ALSO THE BURKHAI-COTTINGHAM SUM RULE

different approaches to instanton phenomenology

instanton liquid model (Kochetov)

- based on instanton Lagrangian for fixed instanton radius
- predicts large instanton contribution to polarized gluon (\rightarrow fig.) and sea quark distribution
- factorization properties not yet clear

dilute gas model (Moch, Ringwald, Schrempf)

- virtuality of γ^* provides dynamical cut for instanton size
- corrections to DIS coefficient functions
- instanton effects suppressed by $e^{-\frac{4\pi}{\alpha_s(\mu)}$

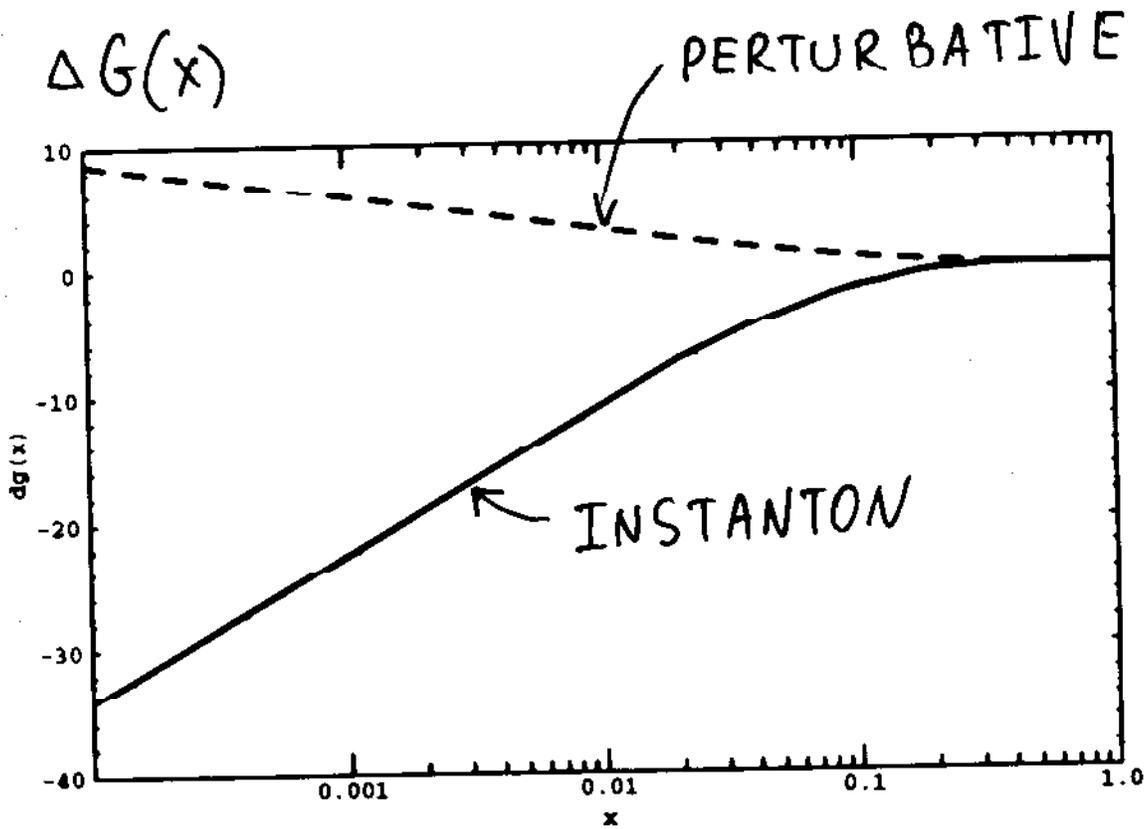
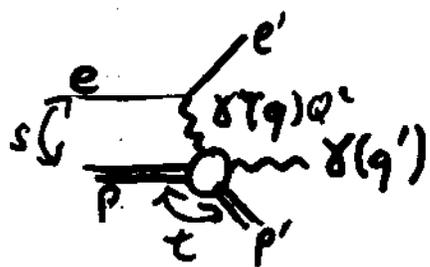


Figure 2: x dependence of the gluon polarization induced by instantons (solid line) and perturbative vertex (dashed line). $\rho_c = 2 \text{ GeV}^{-1}$.

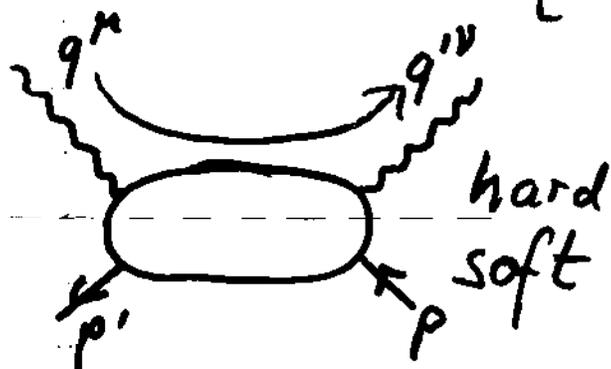
exclusive reaction: $ep \rightarrow ep\gamma$



(+ interference with



In the limit: Q^2, s large } $\Rightarrow \chi(\gamma^*, \gamma)_s$
 t small



$$= T_S^{\mu\nu} + T_a^{\mu\nu}$$

soft part described by off-forward
 parton distributions (OFFPD's)

Diracology, algebra, keep leading terms in $1/Q$ ----



$$= T_B^{\mu\nu} + T_A^{\mu\nu}$$

$$T_B^{\mu\nu} = \frac{1}{2} (\bar{n}^\mu n^\nu + \bar{n}^\nu n^\mu - g^{\mu\nu}) \int dx \left(\frac{1}{x - \mathcal{X} + i\epsilon} + \frac{1}{x + \mathcal{X} + i\epsilon} \right) \\ \times \int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle p' | \bar{q}(-\frac{\lambda n}{2}) \gamma \cdot n q(\frac{\lambda n}{2}) |$$

$$T_A^{\mu\nu} = -\frac{i}{2} \epsilon^{\mu\nu\alpha\beta} \bar{n}_\alpha n_\beta \int dx \left(\frac{1}{x - \mathcal{X} + i\epsilon} - \frac{1}{x + \mathcal{X} + i\epsilon} \right) \\ \times \int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle p' | \bar{q}(-\frac{\lambda n}{2}) \gamma \cdot n \gamma^5 q(\frac{\lambda n}{2}) |$$

$$n^\mu \sim \begin{pmatrix} 1 \\ 0_\perp \\ -1 \end{pmatrix} ; \quad \bar{n}^\mu \sim \begin{pmatrix} 1 \\ 0_\perp \\ 1 \end{pmatrix} ; \quad \mathcal{X} = \frac{Q}{2(p^+)}$$

$$\frac{d\lambda}{2\pi} e^{i\lambda k} \langle p' | \bar{q}(-\frac{\lambda n}{2}) \gamma^\mu q(\frac{\lambda n}{2}) | p \rangle \quad \Delta = p'$$

$$= \bar{u}(p') [H(x, X, t) \gamma^\mu + E(x, X, t) \frac{i\sigma^{\mu\nu} \Delta_\nu}{2m}] u(p)$$

$$\frac{d\lambda}{2\pi} e^{i\lambda k} \langle p' | \bar{q}(-\frac{\lambda n}{2}) \gamma^\mu \gamma^5 q(\frac{\lambda n}{2}) | p \rangle$$

$$= \bar{u}(p') [\tilde{H}(x, X, t) \gamma^\mu \gamma^5 + \tilde{E}(x, X, t) \frac{\Delta^\mu \gamma^5}{2m}] u(p)$$

lation to total quark spin contribution:

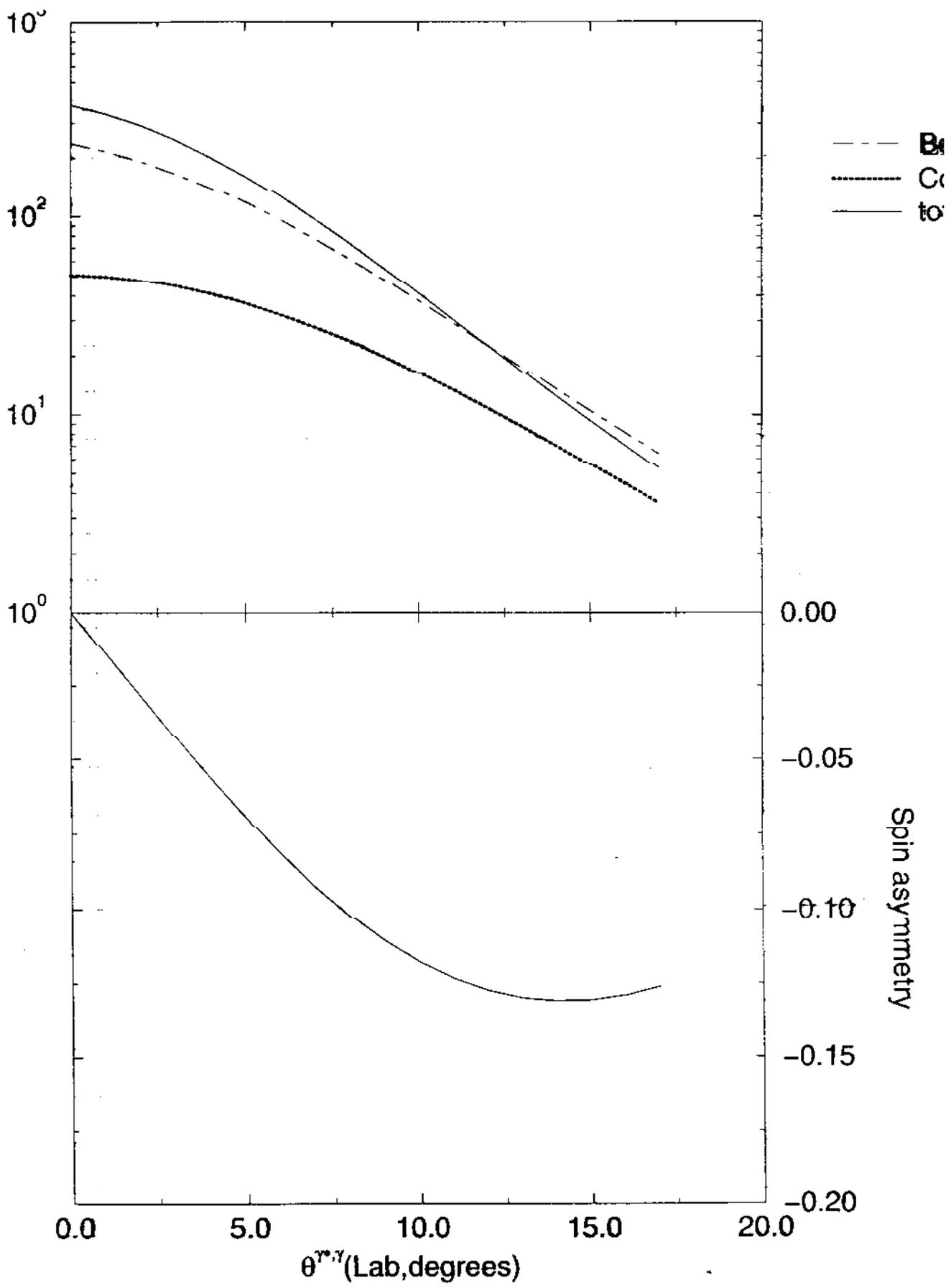
$$\int_0^1 dx [H(x, X, t) + E(x, X, t)] = A(t) + B(t)$$

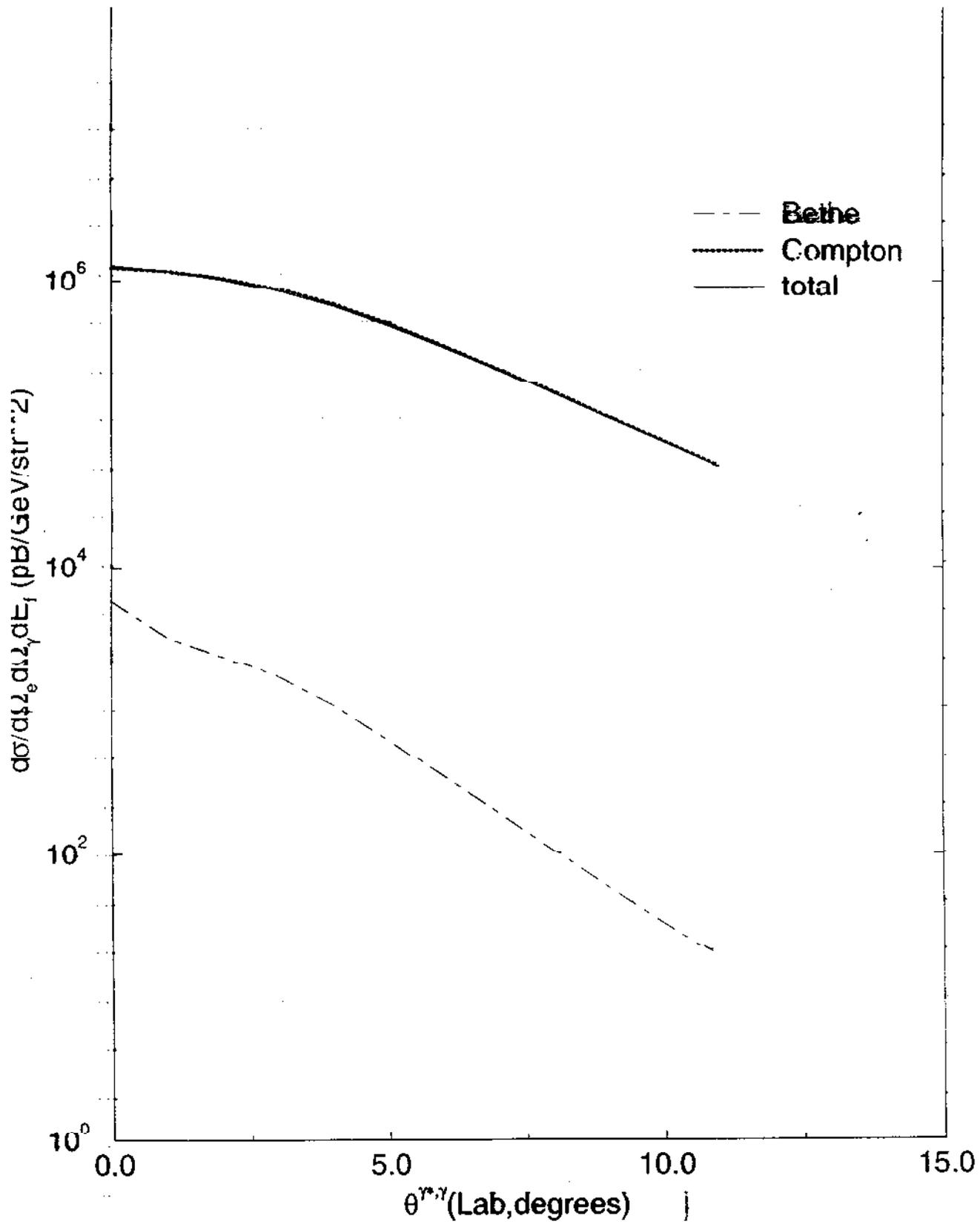
with: $J_9 = \frac{1}{2} [A(0) + B(0)]$ (gauge-dep)

model predictions for DVCS cross section:

use: $H(x, X, t) = q(x) h(t)$ } norm
 $E(x, X, t) = q(x) e(t)$ } to form

→ fig





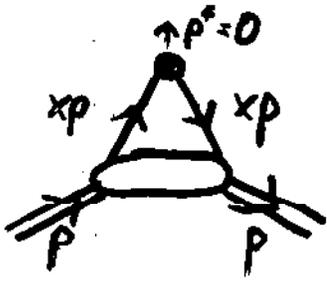
$t = 0.07 \text{ GeV}^2$

$t = 0.77$

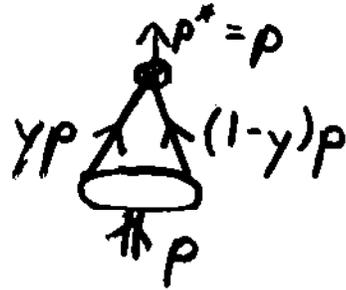
EVOLUTION OF OFF-FORWARD PARTON DISTRIBUTIONS

(Radyushkin
Robasch)

FPD's are hybrids of



and



parton distribution

distribution any
(cf. $\gamma\gamma^* \rightarrow \pi^0$)



→ yields double distribution $F(x, y)$

evolution equation:

$$\left(\mu \frac{\partial}{\partial \mu} + \beta(g) \frac{\partial}{\partial g} \right) F(x, y, \mu) = \int_0^1 d\xi \int_0^1 d\eta \boxed{R(x, y, \xi, \eta, g)} F$$

evolution kernel

$$\text{th: } \int_0^{1-x} dy R(x, y, \xi, \eta, g) = \frac{1}{\xi} P^{AD} \left(\frac{x}{\xi} \right)$$

$$\int_0^{1-y} dx R(x, y, \xi, \eta, g) = V^{BL} (y, \eta, g)$$

- First calculation of the spin-dependent singlet anomalous dimensions

$$u^2 \frac{d}{d\mu^2} O^i(1,0) = \frac{\alpha_s}{2\pi} \int d\alpha_1 d\alpha_2 K^{ij}(\alpha_1, \alpha_2) O^j(1-\alpha_1,$$

$$K^{qq} = 2C_F \left(1 - \frac{1}{2} \delta(\alpha_1) \delta(\alpha_2)\right)$$

$$K^{qg} = -N_F (1 - \alpha_1 - \alpha_2)$$

$$K^{gg} = C_A \left[4(1 - \alpha_1 - \alpha_2) + \left(\frac{11}{6} - \frac{2N_F}{6C_A}\right) \delta(\alpha_1) \delta(\alpha_2) \right. \\ \left. + \delta(\alpha_1) \left(\left[\frac{1}{\alpha_2}\right]_+ - 2 + \alpha_2\right) + \delta(\alpha_2) \left(\left[\frac{1}{\alpha_1}\right]_+ - 2 + \alpha_1\right) \right]$$

$$K^{qg} = C_F \left(1 - \delta(\alpha_1) - \delta(\alpha_2) + \delta(\alpha_1) \left[\frac{1}{\alpha_2}\right]_+ \right. \\ \left. + \delta(\alpha_2) \left[\frac{1}{\alpha_1}\right]_+ + \frac{3}{2} \delta(\alpha_1) \delta(\alpha_2) \right)$$

J. Blümlein, B. Geyer, D. Robaschik
 DESY 97-074

Twist 3:

Results of Bukhvostov, Kuraev, Lipatov & Braun-Balitzky are confirmed

B. Geyer, D. Müller, D. Robaschik 1996 (1)

... 1997

QCD corrections to polarized observables

polarized two-loop splitting functions
 $\Delta P_{ij}^T(x)$ for time-like parton branching a
(Stratmann)

Complete $\mathcal{O}(\alpha_s)$ corrections to the x_F and
distributions in polarized Drell-Yan proc
(TG)

First steps towards polarized Drell-Yan as
non-singlet contributions (Chang, Coriano, Field)

roduction of W^\pm, Z^0 in hadronic collisions is similar to Drell-Yan process.

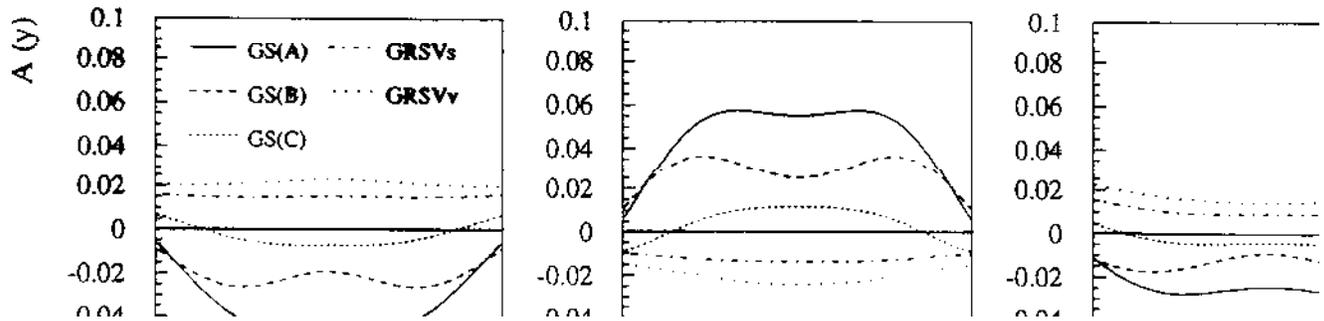
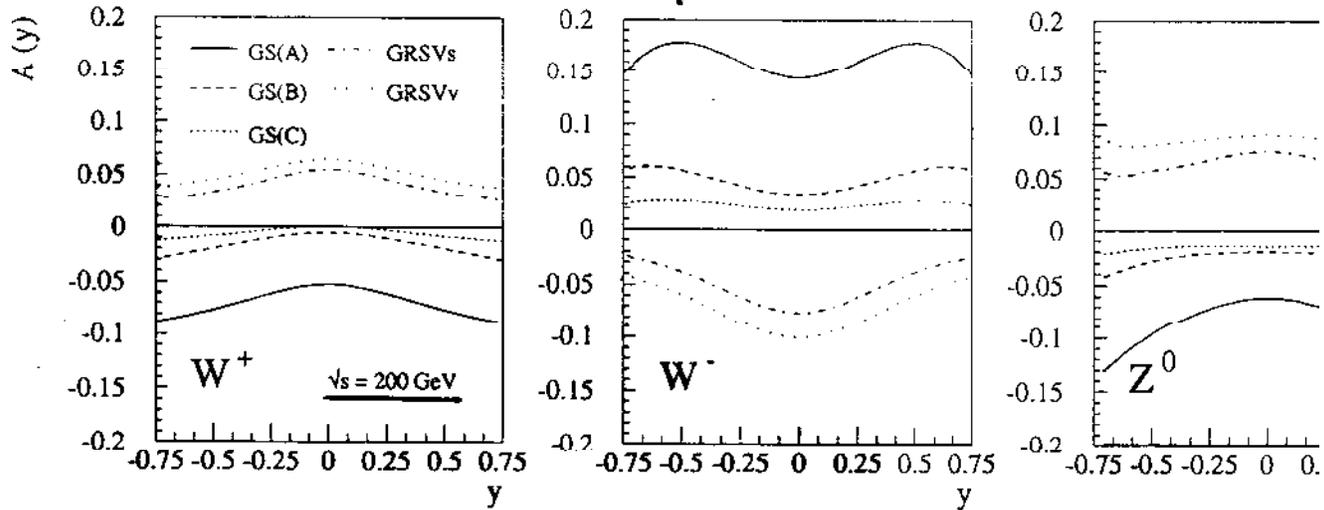
QCD corrections to Drell-Yan process for and to vector boson production are identical

Different vector bosons probe different distributions

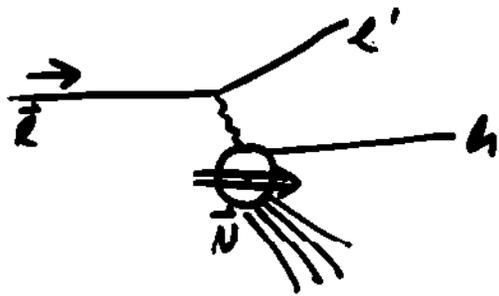
$$A(W^+) \sim \frac{\Delta u}{u} \frac{\Delta d}{d}$$

$$A(W^-) \sim \frac{\Delta d}{d} \frac{\Delta u}{u}$$

$$A(Z^0) \sim \frac{\Delta q_i}{q_i}$$



$$\vec{\ell} + \vec{N} \rightarrow \ell' + h + X$$



Hadron variables:

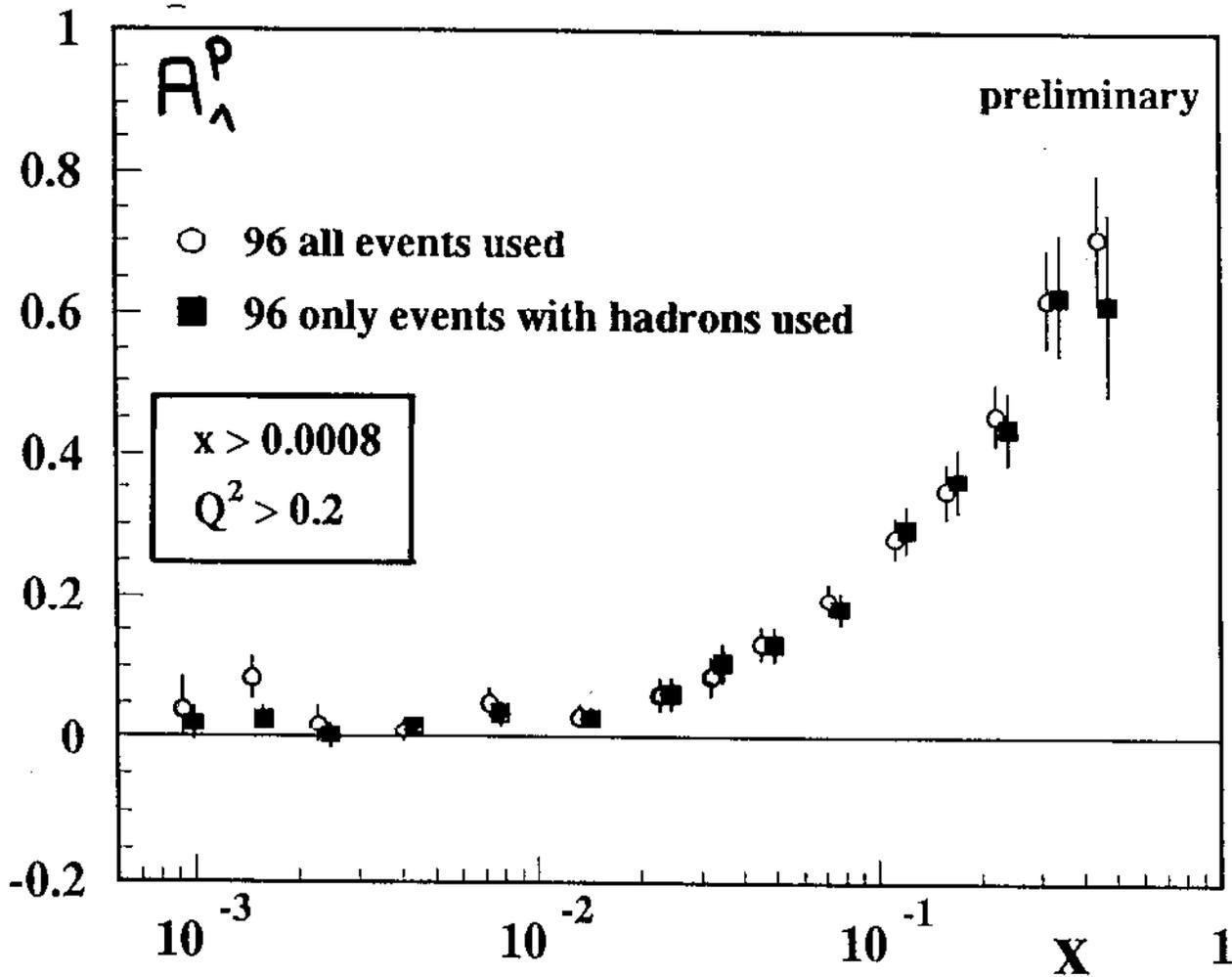
$$z_{\text{had}} = \frac{E_h}{\nu} ; p_{\perp} ; x_F = \frac{p_L}{p_{L, \text{max}}}$$

Motivation:

- 1) Use hadron tag to define deep inelastic event sample (minimize radiative correction \rightarrow)
- 2) Production asymmetries for charged hadron can be used to extract polarized q_c distributions of individual flavour.

RESULTS FOR INCLUSIVE ASYMMETRY A_1^P

- good agreement with stand. anal
- stat. errors at low x smaller by 0.6



- work is going on :
refinement of radiative corr.
systematic errors

fraction of polarized gluons in semi-inclusive DIS (SMC, E. Kabuss)

measure:

$$A_h(x, z) = \frac{G_h^{\rightarrow} - G_h^{\leftarrow}}{G_h^{\rightarrow} + G_h^{\leftarrow}} \sim \frac{\sum e_q^2 (\Delta q \cdot D_q^h + \Delta \bar{q} \cdot D_{\bar{q}}^h)}{\sum e_q^2 (q \cdot D_q^h + \bar{q} \cdot D_{\bar{q}}^h)}$$

$$\mid A_1(x, z) = \frac{G^{\rightarrow} - G^{\leftarrow}}{G^{\rightarrow} + G^{\leftarrow}} \sim \frac{\sum e_q^2 (\Delta q + \Delta \bar{q})}{\sum e_q^2 (q + \bar{q})}$$

→ 6 asymmetries: $A_1^p, A_1^d, A_+^p, A_+^d, A_-^p, A_-^d$

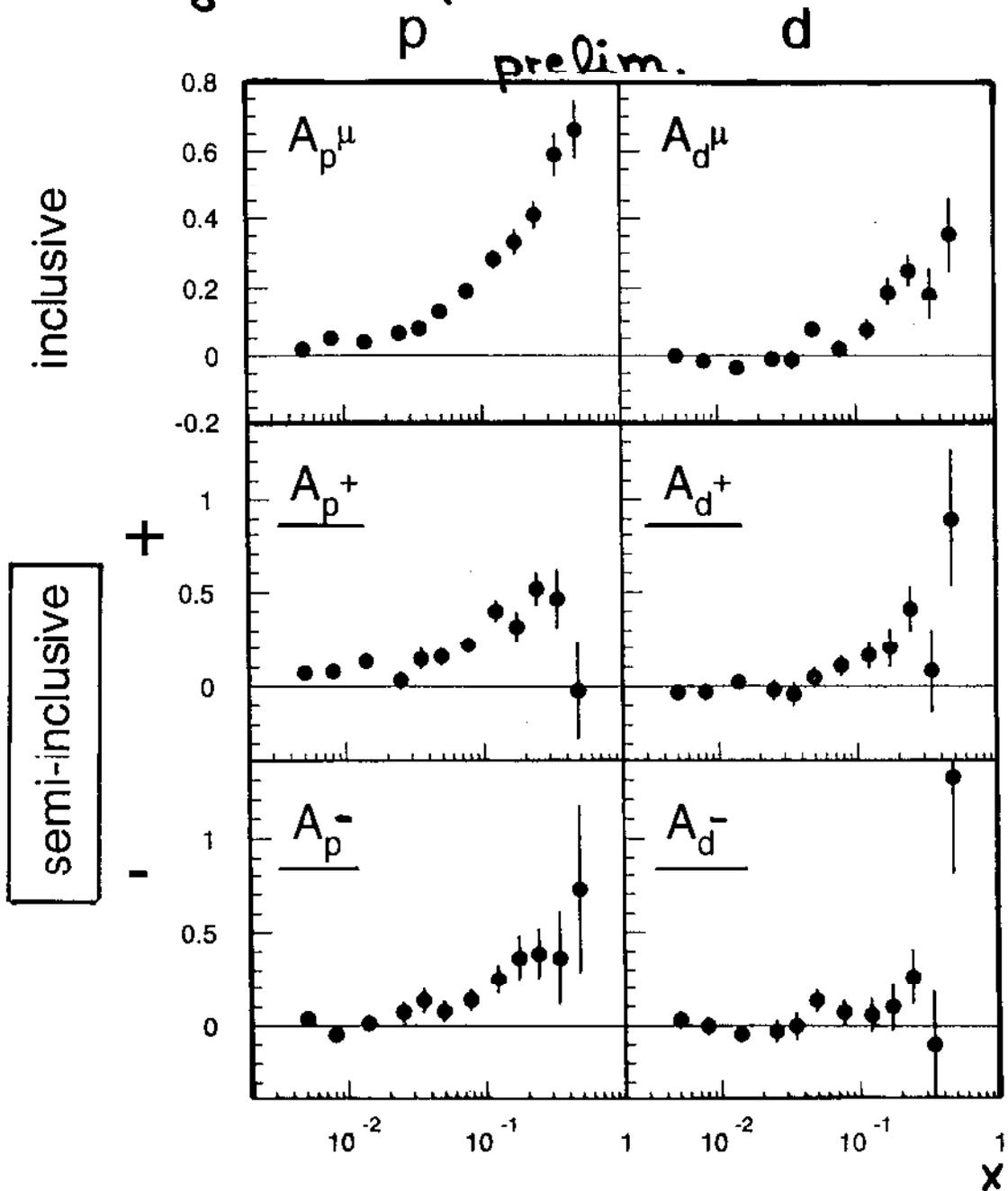
solve: $\begin{pmatrix} A_1^{p,d} \\ A_+^{p,d} \\ A_-^{p,d} \end{pmatrix} = C \left(1, \int D^{\pm}(z) \right) \otimes \begin{pmatrix} \Delta u_v \\ \Delta d_v \\ \Delta \bar{u}_v \\ \Delta \bar{d}_v \\ \Delta s \end{pmatrix} \rightarrow$

HERMES will yield dramatic improvement on this measurement →

- $A_h^{YN} = \frac{1}{f \cdot D \cdot P_b \cdot P_t} A_{exp}^{YN}$

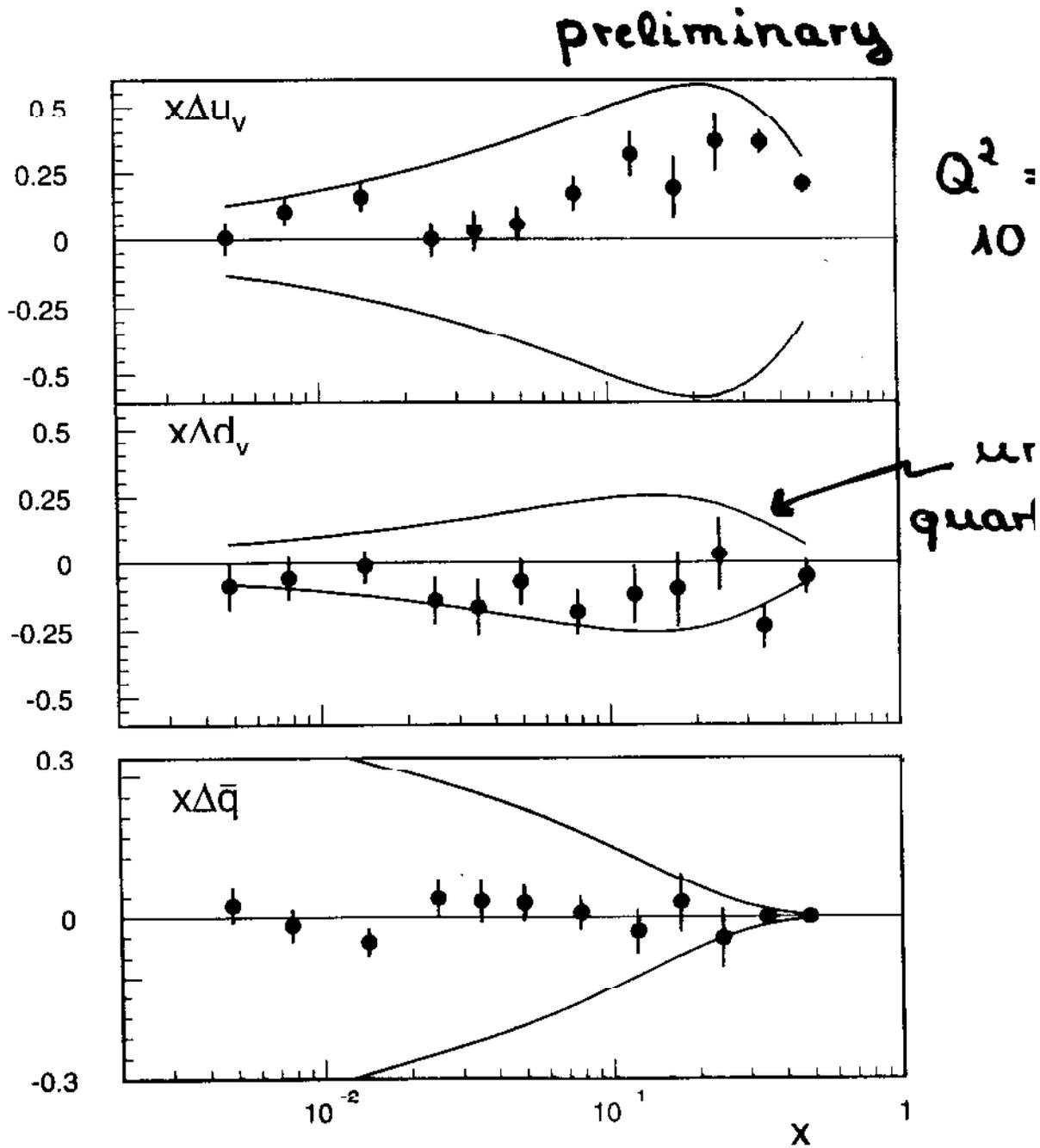
- semi-incl. radiative correction ap

- integrated from $z = 0.2$ to $z = 1$

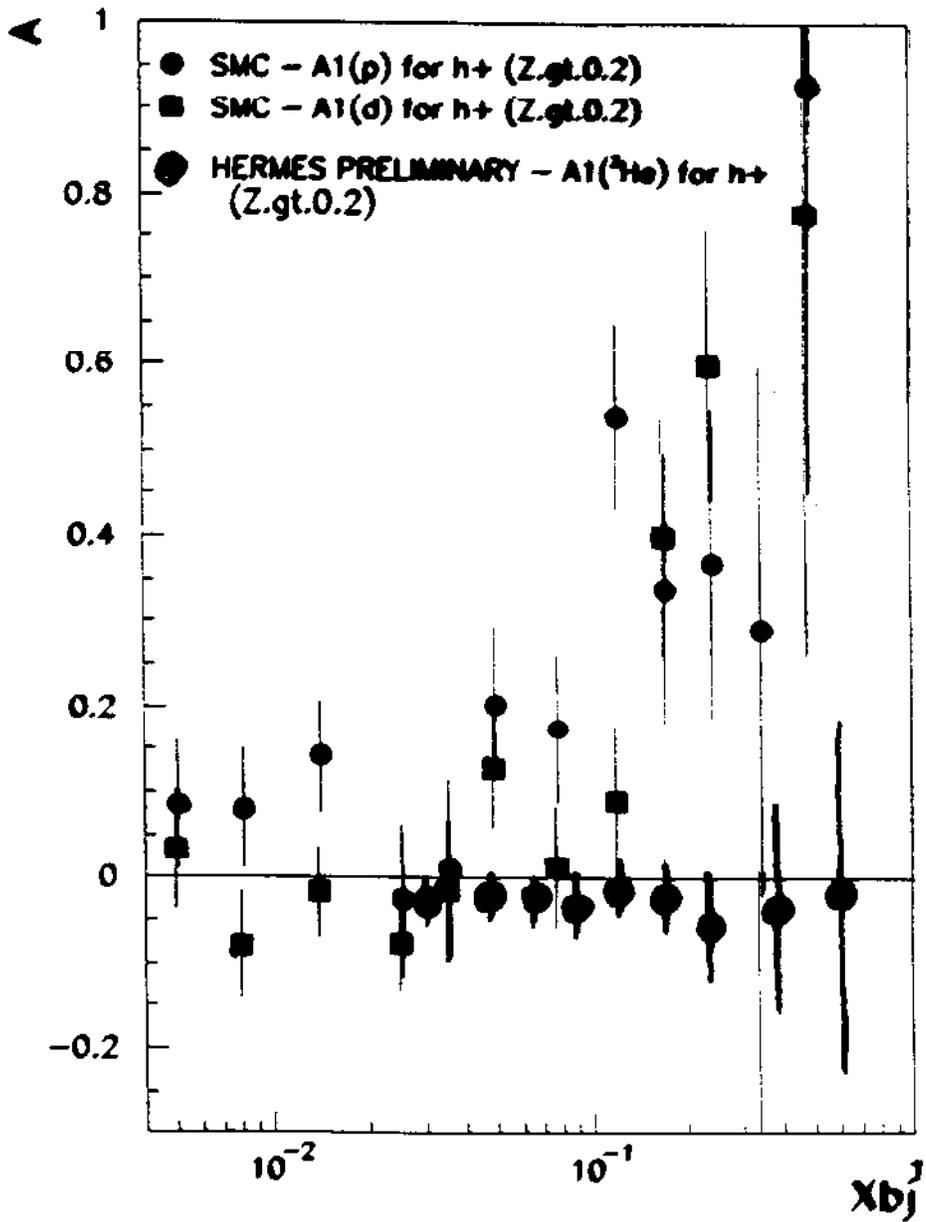


... first ... / stat ...

- $|\Delta\bar{q}(x)| < \bar{q}(x)$ imposed



- main contrib. to systematic errors



Spin transfer in Λ fragmentation

Polarized fragmentation functions $\Delta D_q^h = D_{q\uparrow}^{h\uparrow}$ describe the spin transfer from the fragmenting parton to the final state hadron.

Can be studied in Λ fragmentation, as Λ decay is self-analyzing

Model predictions:

(1) parton model: $\Lambda^\uparrow = (ud)s^\uparrow \rightarrow \Delta D_u^\Lambda = \Delta D_d^\Lambda$

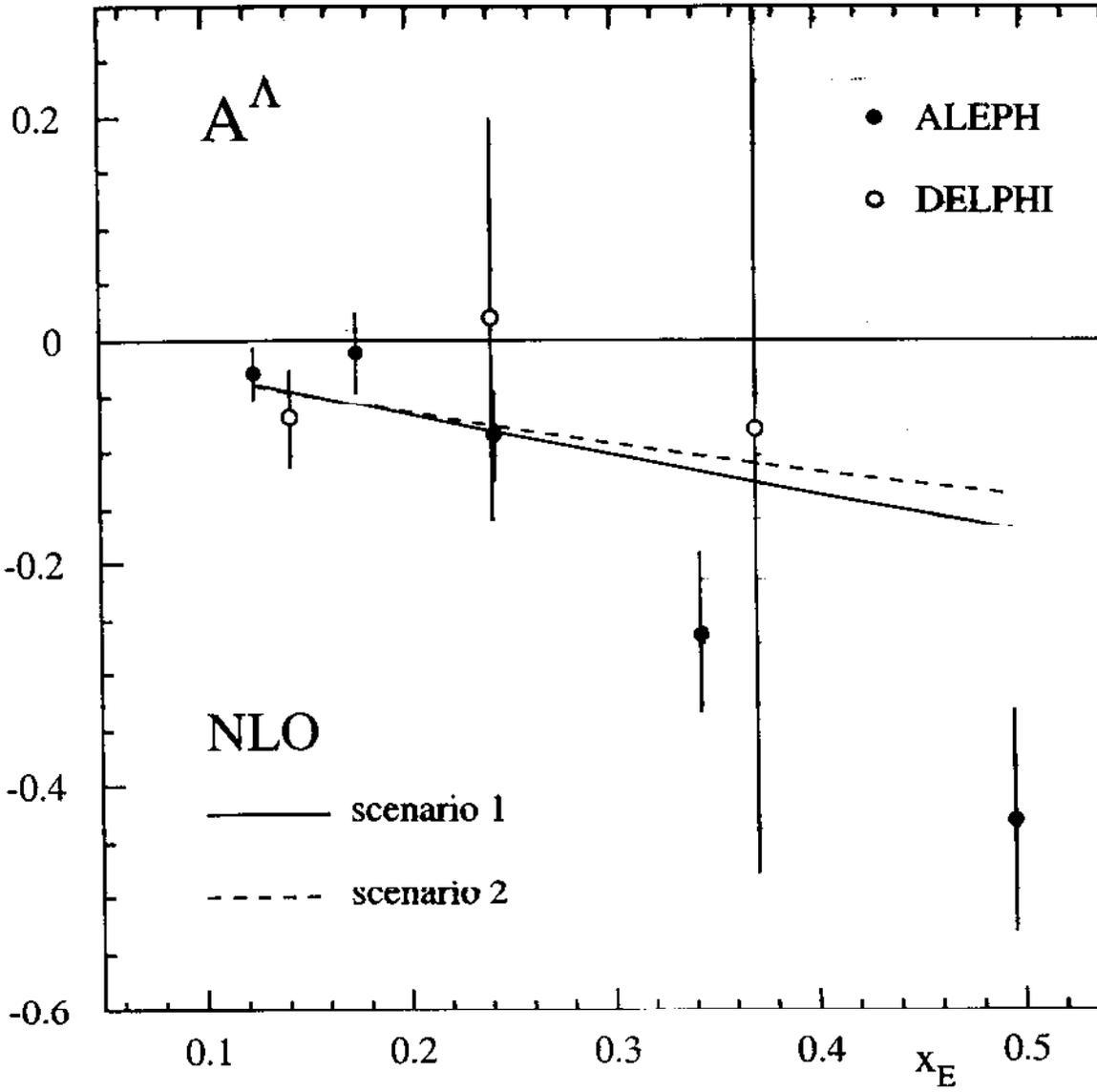
(2) Burkhard-Ioffe: $\Delta D_u^\Lambda = \Delta D_d^\Lambda \approx 0.2 \Delta D_s^\Lambda$

Tests of these models:

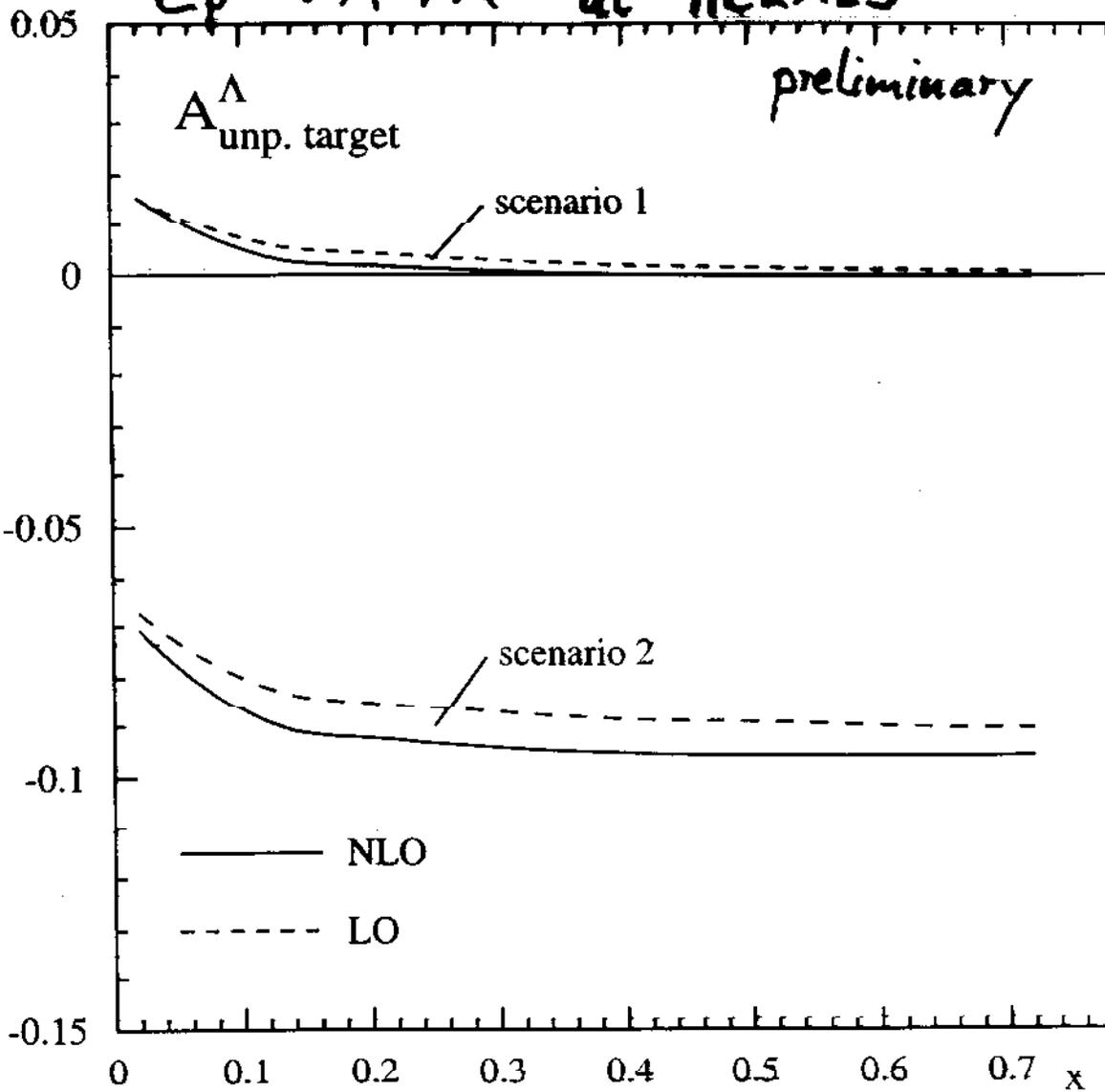
$e^+e^- \rightarrow Z \rightarrow \Lambda^\uparrow + X$: insensitive \rightarrow

$p \rightarrow \Lambda^\uparrow + X$: $|A^{(2)}| \gg |A^{(1)}|$ \rightarrow

$$e^+e^- \rightarrow \Lambda^+ + X$$



$\vec{e}p \rightarrow \Lambda^+ + X$ at HERMES



low polarized $\vec{\mu}\vec{p}$ scattering experiment at C
with dedicated final state identification. \rightarrow

physics programme:

- measure $\frac{\Delta G}{G}$ ($x \approx 0.15$) from photoproduction
of open charm: 

method	$\delta(\frac{\Delta G}{G})$
tag $D^0 \rightarrow K\pi$ pairs	0.21
+ D^* tagging	0.14
+ $p_T(D^0) < 1 \text{ GeV}$ cut	0.11

- improve $g_1^{p,d}(x, Q^2)$ measurement
- study semi-inclusive asymmetries
- $\frac{\Delta G}{G}$ from high- p_T tracks (study in p_1)

use H1 and ZEUS to study polarized ep collisions at $\sqrt{s} = 300 \text{ GeV}$, $\int \mathcal{L} dt = 200 \text{ pb}^{-1}$

polarization of the proton beam: technical challenge
potential physics programme:

- $g_1(x, Q^2)$ at small x \rightarrow fig.
- $\Delta G(x, Q^2)$ from dijets \rightarrow fig.
- polarized weak structure functions
- polarized photon structure
- polarization phenomena in vector meson production
- polarization and diffraction (?)
- polarization in large x , large Q^2 events
-

joining Workshop on "Physics with Polarized Protons"
(<http://www.desy.de/~geht/heraspin>)

Proton Spin Structure Function

(Meziani, E154)

xg_1^p

0.040

0.035

0.030

0.025

0.020

0.015

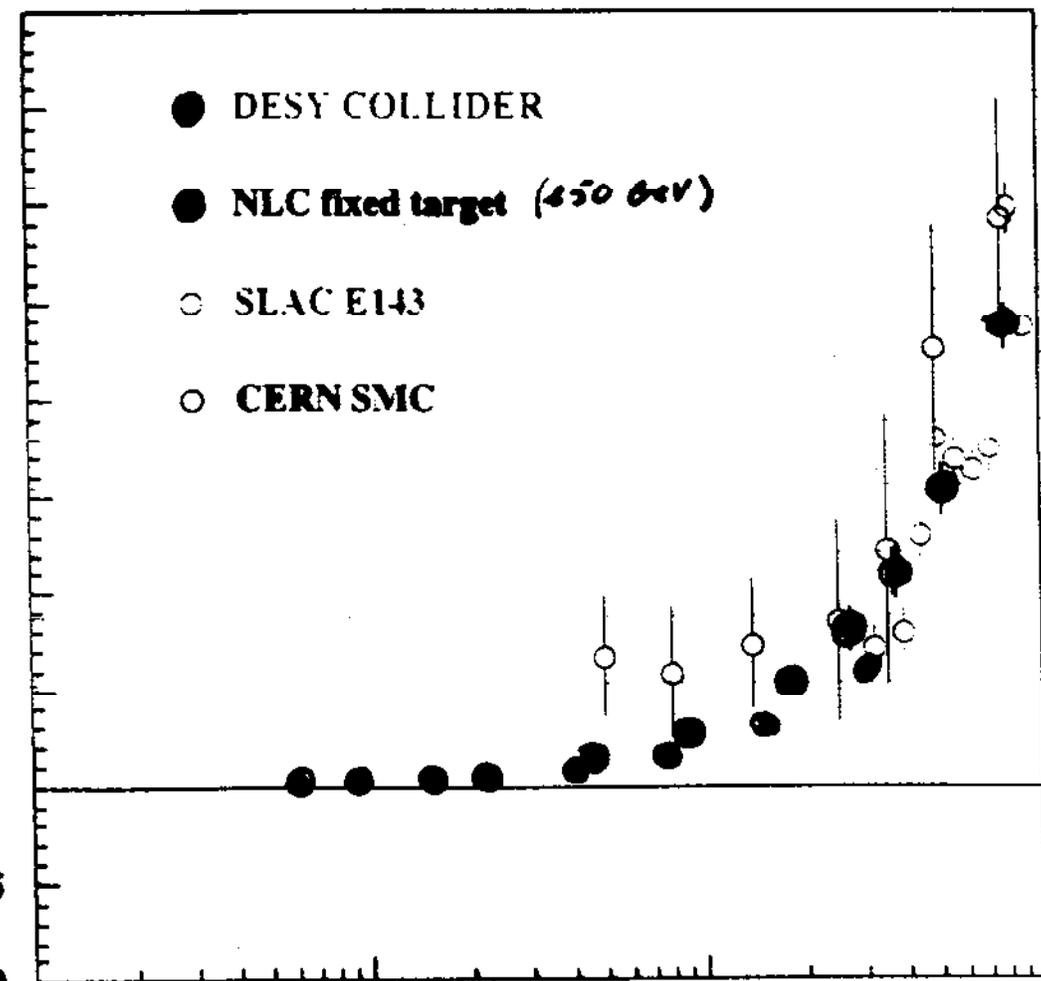
0.010

0.005

0

-0.005

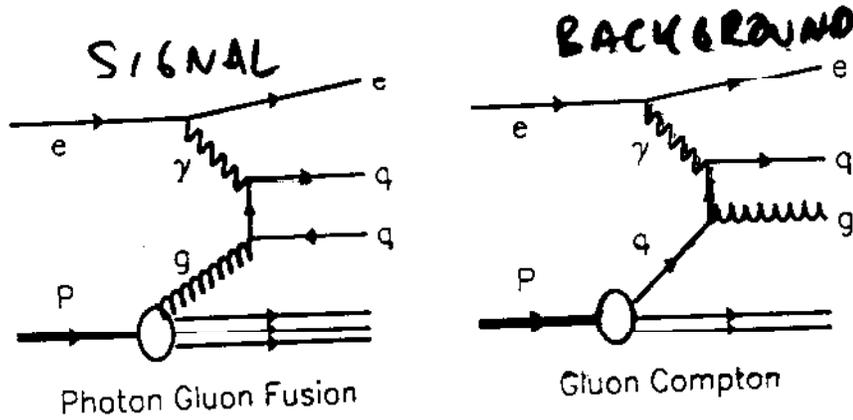
-0.010



x

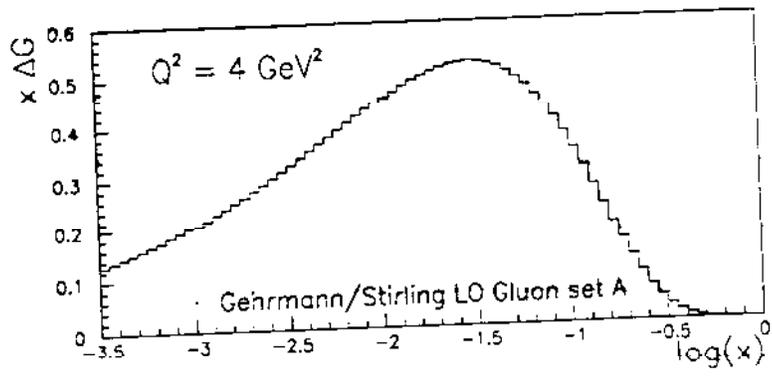
$(\Delta G/G)$ from boson-gluon-fusion in polarized e-p scattering at HERA

DE ADU
FELTES
KONNE
MAUL
MIRIA
ERDEL
SERAFI
WU



- Measure crosssection for (2+1)-jet events
- In LO: $\sigma \sim \alpha_s \times G \Rightarrow \frac{\Delta G}{G} \sim \frac{1}{P_e P_p D} \times \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}$

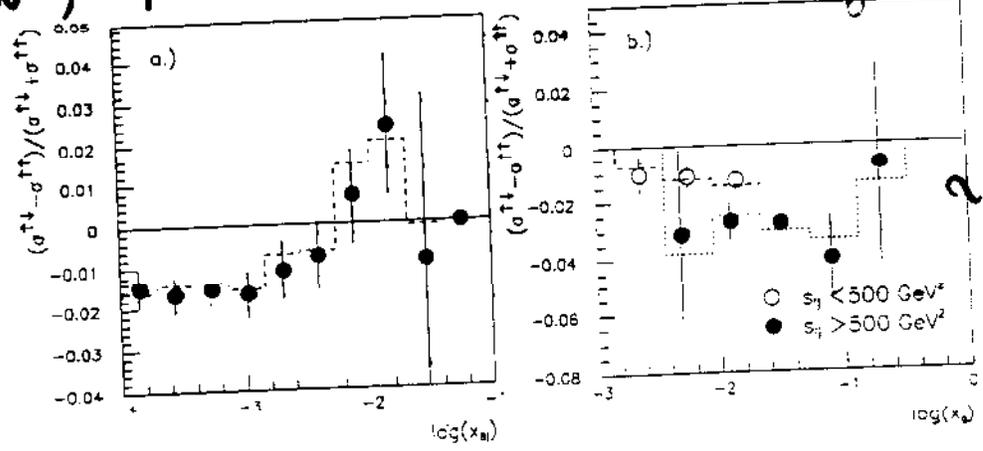
$\delta(\frac{\Delta G}{G}) \sim 10\%$



$Q^2 > 5 \text{ GeV}^2; p_T^{\text{jet}} > 5 \text{ GeV}$

$0.002 < x_g < 0.2$

ASYMMETRY



~ FEW%

- Asymmetries vs. a) $\log(x_{Bj})$ and b) $\log(x_g)$ at the parton level (with error bars)

Summary

- precision on $g_1(x, Q^2)$ has improved considerably with new data from HERMES, E154, SMC
- behaviour of $g_1(x, Q^2)$ at small x unknown
→ dominant source of uncertainty on sum rule measurements
- recent theoretical developments
 - lattice measurement of polarized pdf
 - instanton calculations
 - DVCS
 - integral relations for polarized sfi.
 - spin-dependent two-loop timelike split
- future experiments
 - semi-inclusive programme at HERA
 - COMPASS

Many thanks to:

- all participants of the "Spin physics" working group
- all (21) speakers
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K. Rith